111

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Introduction

The purpose of this project was to use NASA technology to assist the US Army Program Executive Office for Ground Combat and Support Systems, Project Managers Office, Bradley Fighting Vehicle System, (PM-BFVS), in the assessment of motion sickness incidences within the Command and Control Vehicle (C2V). The C2V contains four workstations where military personnel are expected to perform command decision operations during combat conditions. This research meets the NASA Human Exploration and Development (HEDS) objective of transferring NASA technology to Earth-based applications. The present study also serves as a demonstration of this technology for evaluating environmental impact on individuals serving as either passengers or crew on land, sea, air and space vehicles.

A recently completed study conducted at the Yuma Proving Grounds (Cowings, Toscano & DeRoshia, 1998), demonstrated that NASA's methods employed for assessment of environmental impact on soldier health and performance could be successfully conducted under operational field test conditions. Eight active duty military men (US Army) at the Yuma Proving Grounds in Arizona participated in this study. All subjects were given baseline performance tests while their physiological responses were monitored on the first day. On the second day of their participation subjects rode in the C2V while their physiological responses and performance measures were recorded. Self-reports of motion sickness were also recorded.

Results showed that only one subject experienced two episodes of vomiting. However, seven of the eight subjects reported other motion sickness symptoms. The most frequently reported symptom was drowsiness, which occurred a total of 19 times. Changes in physiological responses were observed relative to motion sickness symptoms reported and the different environmental conditions (i.e., level, hills, and gravel) during the field exercise. Performance data showed an overall decrement during the C2V exercise. These findings suggest that malaise and severe drowsiness can potentially impact the operational efficiency of C2V crew. However, a number of variables (e.g., individual's sleep duration prior to the mission, previous experience in the vehicle) were not controlled and may have influenced the results. Most notable was the fact that subjects with prior experience in the C2V all occupied seat 4 (located furthest forward) which was anecdotally reported to be the least provocative position. Nonetheless, it was possible to determine which factors most likely contributed to the results observed. It was concluded that conflicting sensory information from the subject's visual displays and movements of the vehicle during the field exercise significantly contributed to motion sickness symptoms observed in both this study and the earlier study conducted at Camp Roberts, by the US Army Research Laboratory (ARL).

The objectives of the Yuma study were successfully met. The use of three converging indicators, (1) physiological monitoring, (2) subject self-reports of symptoms and, (3) measurements of performance, were an effective means of evaluating the incidence of motion sickness and the impact on crew operational capacity in the C2V. It was recommended that a second study be conducted to further evaluate the effect of seat position and orientation on motion sickness susceptibility.

The present study was a modification of the Yuma study using a larger sample population (N=24), and three different vehicle configurations. The primary goal of this investigation was to evaluate the impact of C2V mobile field operations on crew performance, and to determine the effects of vehicle configuration on motion sickness susceptibility, physiology and performance.

METHODS

<u>Subjects:</u> Twenty-four active duty military personnel (8 women and 16 men between the ages of 18 – 34) participated in this study**.** Subjects were medically qualified for participation in these tests following physical examinations performed by Army physicians. Subjects were briefed on the experimental procedures, and their voluntary consent was obtained prior to the start of tests. Subjects were instructed to abstain from consuming alcohol or medication (i.e., anti-motion sickness drugs or antihistamines) throughout their participation in this study. The research protocol was reviewed and approved by the Institutional Review boards of both NASA Ames Research Center and the Army Research Laboratory.

<u>Apparatus</u>: **Physiological Measures**

The Autogenic-Feedback System-2 (AFS-2) is a portable belt-worn ambulatory monitoring system designed to monitor human physiological responses. This system was developed and tested on astronauts during a space shuttle mission in 1992. The physiological measures listed below were recorded on the AFS-2, (see Figure 1), which includes a garment, transducers, biomedical amplifiers, a digital wrist-worn feedback display and a cassette tape recorder. The entire instrument is powered by a self-contained battery pack.

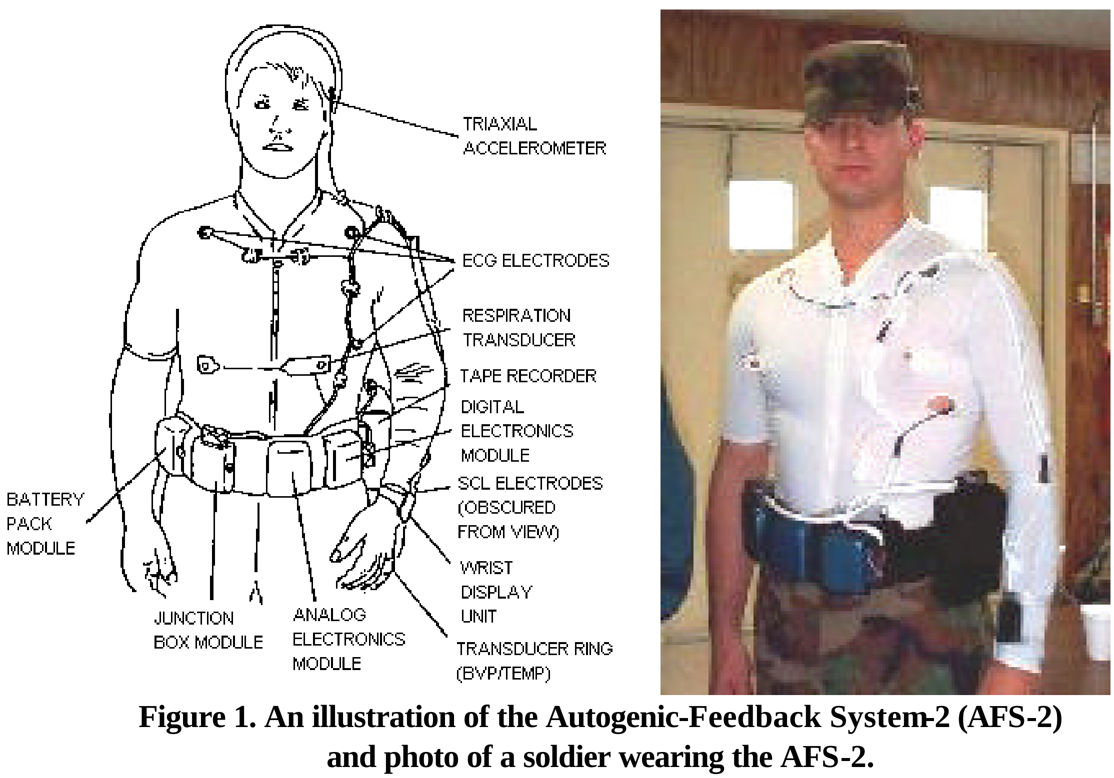

Figure 1. An illustration of the Autogenic-Feedback System-2 (AFS-2) and photo of a soldier wearing the AFS-2.

(1) Electrocardiograph (ECG): Pregelled disposable electrodes were placed on the chest just below the left and right clavicles (distally), and on the left midclavicular line over the fourth intercostal space.

(2) Respiration Rate (RR): Respiration amplitude and frequency were measured with a piezoelectric transducer attached to the garment with snaps over the chest.

(3) Finger Pulse Volume (FPV): Relative changes in peripheral vasomotor activity were monitored using an infrared photoplethysmograph. A miniature light emitter/diode mounted within a ring transducer was placed on the inner surface of the small finger on the left hand.

(4) Skin Temperature (ST): A solid-state temperature transducer (Analog Devices, model AD590) was mounted within the same ring as the FPV transducer. ST was used as a relative measure of peripheral blood volume.

(5) Skin Conductance Level (SCL); Absolute changes in the electrolytic properties of the skin were monitored from disposable electrodes. These pregelled, self-adhesive electrodes were mounted on the volar surface of the left wrist.

(6) A triaxial accelerometer – was used to measure head and upper-body movements of subjects during field tests within the C2V. This device was attached to the soldiers' hats or helmets with tape.

DELTA Performance Tasks

The DELTA human performance measuring system is an upgraded software version of the Automated Performance Test System (APTS), which was developed as an assessment tool for human performance (Kennedy et. al, 1985). The APTS was developed with emphasis on within-subjects, repeated-measures designs, and has been proven both reliable and valid in a number of investigations, and administration takes approximately 15 minutes or less, depending upon the test battery configuration. The DELTA test battery has been used extensively to study the effects of environmental and chemical stressors on human performance. Our own research group has used the APTS version of this computer based performance task battery to successfully to evaluate the effects of promethazine on human performance and motion sickness susceptibility (Cowings, et. al, 1995) and during bed-rest studies (DeRoshia & Greenleaf, 1993). For some subtests, the performance metric was "accuracy", (number of correct responses minus number of errors); or "speed" (responses per second). The manual dexterity tests were evaluated on the number of alternate key presses in the time allowed. A brief description of the seven subtests used in this experiment is provided below.

Three-choice reaction time (60 seconds, difficulty level 3). This test involved the presentation of a visual stimulus and measurement of response latency to the stimulus. The subject's task was to respond as quickly as possible with a key press to a simple visual stimulus. On this test, three "outlined" boxes were displayed and one of the three boxes was "filled". A short tone preceded the filling of a box to signal that a "change" in the status of a box was about to occur. The box changed from "outlined" to "filled". The subject was required to scan the boxes for the change and then press the numeric key corresponding to the box that had changed. This test measures response latency between the presentation of the stimulus and the response in milliseonds (metric=speed).

Code substitution (75 seconds). The computer displayed nine characters across the top of the screen. Beneath them, the numbers one through nine were displayed within parentheses. The subject's task was to associate the number with the character above it. This is called the subject's "code". Under the code were two rows of characters with empty parentheses beneath them. The subject responded by pressing the number associated with the character from the code above. When the subject completed a row, the bottom row moved to the top, and a new row appeared below. This is a mixed associative memory and perceptual test with visual search encoding/decoding and incorporates memory recall and perceptual speed. (metric=accuracy).

Pattern comparison (75 seconds). The task involves comparing two patterns of asterisks that are displayed on the screen simultaneously. The subject's task was to determine if the patterns are the same or different and responded by pressing "S" or "D" key. This is a test of integrative spatial function and may be compared to the ability of recognizing changes in radar screen or map displays. (metric=accuracy).

Preferred hand tapping (10 seconds). In this test, the subject was required to press the indicated keys as fast as possible with two fingers of the preferred or dominant hand. Correct responses were based on the number of alternate key presses made in the allotted time. **Non-preferred hand tapping** was similarly conducted using the non-dominant hand. These tapping tests measure manual motor skill and coordination. (metric=number of alternate key presses).

Grammatical reasoning (90 seconds). Stimulus items were sentences of varying syntactic structure (e.g., A precedes B) accompanied by a set of letters (e.g., AB). The sentences were generated from possible combinations of five conditions: (1) active versus passive wording; (2) positive versus negative wording; (3) key words such as "follows" and "precedes;" (4) order of appearance of the two symbols within the sentence; and (5) order of the letters in the simultaneously presented symbol set. The subject's task was to read and comprehend whether the sentence correctly described the sequence of symbols, which appeared on the screen to the right of the sentence. The subject responded by pressing the "T" (true) or "F" (false) keys. This test measures cognitive reasoning, logic and verbal ability and assesses an analytic function. (metric=accuracy).

Mankin spatial transformation test (60 seconds). This test presents a figure of a sailor on the screen with a box below his feet and a box in each hand. A pattern (♥ ♥ ♥ ♥ ♥ ♥ or ♦ ♦ ♦ ♦ ♦ ♦) appears in the box below which matches the pattern in the box in one of his hands. The figure stands either facing away or toward the subject (right-side up or upside own). The objective of this task is to determine which hand (right or left) matches the objects that appears in the box on which the sailor is standing. The subject responds by pressing one of the two arrow keys, (i.e., to indicate left or right hand). This test measures the ability to spatially transform mental images and determine the orientation of a given stimulus. (metric=accuracy).

Symptom Diagnostic Scale. (60 seconds)

At specific intervals test subjects within the C2V were asked to report any symptoms they may be experiencing using computers at their workstations. A computer program allowed the subject to rate his own symptoms using a standardized diagnostic scoring procedure referred to as the Coriolis

Sickness Susceptibility Index, or CSSI (Graybiel, Wood, Miller, & Cramer, 1968; Cowings, et. al, 1986). Table 1 below shows the questions presented to each test participant.

The presence or absence and/or strength of symptoms were assessed subjectively by the subject (none “0”, mild "1,” moderate "2,” or severe "3"). These symptoms included drowsiness, sweating, salivation, pallor and nausea. Other symptoms were rated as Additional Qualifying Symptoms (ADQ), and were scored as “none, mild or moderate” levels only. These included increased warmth, dizziness and headache. Stomach sensations were evaluated on five levels. Stomach awareness, was described as not nausea and not particularly uncomfortable, but as an increased awareness of the stomach (e.g., hunger). It was scored as either none (0) or mild (1). Stomach discomfort was described as not nausea, but becoming increasingly uncomfortable (e.g., lump in the throat or stomach distended by gas). It was scored as either none (0), or moderate (2). Nausea was reported when it could clearly be differentiated from stomach awareness and stomach discomfort, and was reported as none (0), mild (1) moderate (2), severe (3). Frank vomiting was indicated as “yes” or “no” and was enumerated by the responding to the question, “how often?”

TABLE 1. Symptom Diagnostic Scale

Severity Level	**none**	**mild**	**moderate**	**severe**
	0	**1**	**2**	**3**
Are you feeling warmer?				**--**
Do you have any dizziness?				**--**
Do you have a headache?				**--**
Are you drowsy?				
Are you salivating more?				
Do you have facial pallor?				
Are you sweating?				
Do you feel stomach awareness?			**--**	**--**
Do you have stomach discomfort?		**--**		**--**
Do you have any nausea?				
Have you vomited today?	**yes____**		**no_____**	
If yes, how often?				

The different symptoms and symptom severity were “weighted” by the experimenter when calculating a malaise level after tests have been completed. Motion sickness scores greater than 0 and less than or equal to 2 points represent mild malaise, scores greater than 2 and less than 8 represent moderate malaise; scores of 8 or higher represent severe malaise with 16 points scored for vomiting (i.e., frank sickness).

Mood/Sleep Scale. (60 seconds). Immediately following the Diagnostic Scale, a second program queried the subject on his current mood and alertness. A 10-point visual-analog scale (DeRoshia & Greenleaf, 1993) was used to input responses to questions. The subject moved a cursor on a slide bar presented on his screen with the left/right arrow keys. There were descriptive adjectives at each end of the slide-bar, and the subject's task was to position the cursor to enter his response. The higher the score, the more favorable the response. Lastly, the scale queried subjects on sleep quality by asking if they had trouble falling asleep and how many times they awoke during the previous night. Table 2 shows the specific mood states and sleep questions.

TABLE 2. Mood/Sleep Scale

Motivation	Bored(0)---------------------Interested(10)
Arousal state	Sleepy (0)------------------------Alert(10)
Fatigue Level	Weary (0)---------------------Energetic(10)
Ease of concentration	Very low (0)-------------------Very high(10)
Psychological Tension	Tense (0)----------------------Relaxed (10)
Elation	Sad (0)-----------------------Happy (10)
Physical discomfort	Very high (0),-----------------Very low (10)
Contentedness	Unpleasant (0)------------------Pleasant(10)
Trouble falling asleep	Much worse (0),-----------------Much better (10)
How many times did you wake up last night	(0-6)? Amount ____________

Vehicles

Three vehicle configurations were tested in this experiment. Vehicle 1, oblique, where the seat 4 faced forward and the remaining three seats were at a 20-degree angle from the direction of travel. Vehicle 2, perpendicular, where seat 4 faced forward, but the remaining three seats were at a 90 degree angle from the direction of travel. And Vehicle 3, 4-forward, in which all four seats faced toward the direction of travel. Figure 2 below is a diagram of the interior seat orientation of these vehicles. Figure 3 shows the locations of the computer workstations in the oblique and 4-forward vehicles.

Oblique **Perpendicular** **4-forward**

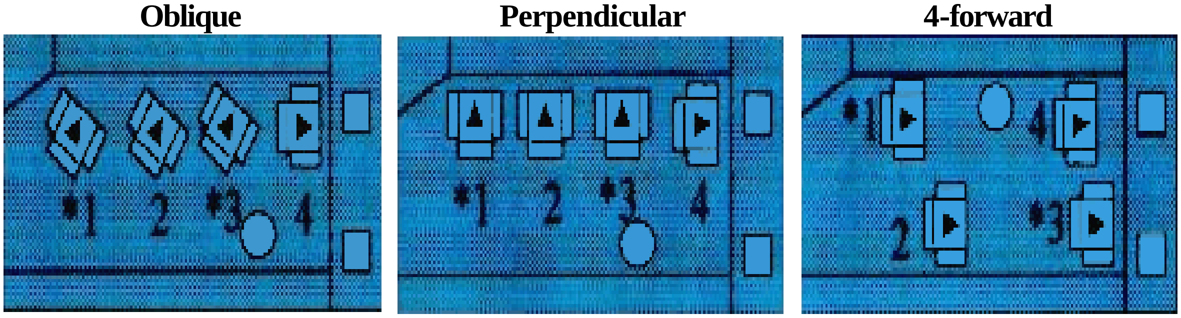

Figure 2. Seat configurations in the three vehicles tested.

Figure 3. Inside view of computer work stations in the oblique (left) and 4-forward (right) vehicles.

<u>Procedures</u>

Each subject participated for 15 days in this study: 2 days of classroom instruction in an office facility (4-5 hours each day); 12 days of field tests in the C2V (4-5 hours per day), and 15 minutes of post-field test performance conducted at the end of the last field test, (15 subjects) or two days after the last field test (8 subjects).

Classroom Instruction

On the first training day, subjects received an experiment briefing from NASA and Army collaborators. During the two classroom instruction days, all soldiers were trained on the Delta task battery (four trials per day, 8 total), AFS-2 system operation, and methods for rating their symptoms. The Delta task batteries, mood and symptom reporting scales were presented on a computer system identical to those mounted in the C2V. Investigators worked with soldiers one-on-one, (8 soldiers per day) to assure their familiarity with test procedures and operation of the AFS-2. On one day of the classroom instruction, each soldier was required to wear the AFS-2, which recorded “baseline” data over a 4-5 hour period. Soldiers were also trained by ARL personnel to perform another set of tasks (not scored) using laptop computers. These additional performance tasks, (Computer Controlled Automated Battery - CCAB) and manual tasks (map reading, radio communication), were also administered during the 4-hour field tests in the C2V. The purpose of these additional tasks was to occupy the soldiers during field tests when the NASA tasks were not being performed, and they simulated functions typically performed by C2V crew.

In addition to training the test participants, six individuals who were designated data collectors, also received instruction on experiment methods. The data collectors assisted the soldiers in donning and doffing the AFS-2 on the field test days. They took subject’s vital signs (pulse, temperature and blood pressure), before and after C2V tests and assured that each soldier was assigned to the proper vehicle and seat required by the experimental design. Further, they were assigned to ride with the subjects during the actual field tests. The data collectors received radioed instructions, relayed by the vehicle driver from an experiment monitoring station. In this station, an assigned duty officer would call out the start times for specific tasks to be performed. Data collectors were then required to inform the soldiers within their vehicles, and make written notes of any problem (i.e., vehicle, hardware or software malfunctions), encountered during the day.

Figure 3 shows pictures of the classroom instruction setting. The photos on top show soldiers receiving individual instruction on the operation of the Delta task batteries, mood and diagnostic scales. Laptop computers used for training on the CCAB tasks were on adjacent tables. The lower photos show the screen views that soldiers observed when performing the Mankin (left) and Code Substitution tasks (right). Figure 4 shows the setting for training operation of the AFS-2 ambulatory monitoring system and for teaching data collectors their required duties during the experiment.

Figure 3. Training on performance tasks, mood, sleep and diagnostic scales.

Figure 4. Training of data collectors and subjects on AFS-2 operation and daily procedures.

C2V Field Tests

Following classroom training, each subject was required to ride four times in each of the three vehicles. During each C2V test, subjects were assigned to a different seat in the vehicle. Figure 4 below shows the scheduled activities on field tests days, and the distribution of tasks performed by subjects during each 4-hour test. Following an initial "Parked " condition (15-20 min. duration), vehicles proceeded through four "Move" conditions (approximately 40-min. duration), interspersed with four "Short-halt" conditions (15-20 min) including one Short-halt at the end of the field tests. Physiological data were only collected on those days when a subject was assigned to seat 1 or seat 3. NASA task batteries, mood and diagnostic scales were collected only during the Parked condition, two of the Moves (1 and 4) and three of the Short-halt conditions (2,3 and 4). Physiological data tapes, computer task files and information on each subject as well as test schedule changes were sent to NASA and university collaborators after the completion of each test day.

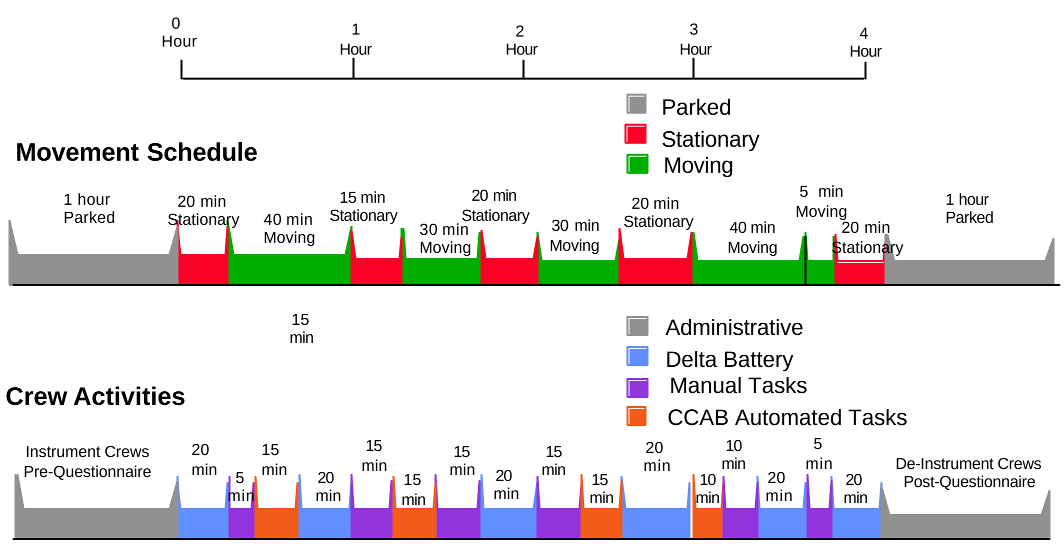

Figure 4. Daily schedule of field test movement profile and crew activities.

Figure 4 above shows when the Delta battery (which included mood and diagnostic scales), manual and CCAB tasks were administered. The red and green areas indicate when the vehicle was stationary or moving. The gray areas before and after the field test show when soldiers donned and doffed the AFS-2, and when "entry' and "exit" questionnaires (e.g., prior night's sleep, medications taken, level of motivation) were administered.

C2V Test Schedule

An optimal experimental design required that subject assignment to vehicles and seats be counterbalanced. However, this was not possible because vehicle 2, perpendicular, was not available until near the end of the experiment. Vehicles 1 and 3 (oblique and 4-forward) operated side-by-side, with each vehicle making the same duration move and short-halt excursions whenever possible. Some of the scheduled test days were canceled and later rescheduled because of problems encountered with vehicle operations or computer hardware and software failures.

Table 4 below shows the complete experiment schedule as it was conducted over a 28-day period. The vehicles and seats are designated as V1-3, (oblique, perpendicular and 4-forward), and S1-4 (seats 1 to 4). The first four days, labeled P1-P4, represented "pilot" tests, during which field operations were tested, and procedural problems resolved. The remaining days were labeled D 1-24. As can be seen from this table, vehicle 2 was not available until D-15.

Subjects 1-8, and 17-24 were always tested in the morning, between 8:00 AM and noon, while subjects 9-16 were tested in the afternoon from 13:00 to 17:00. All subjects were tested on alternate days, allowing one day of rest between C2V exposures. On alternate days throughout the experiment, tests were conducted in the AM only (subjects 17-24) allowing time for vehicle maintenance and repair in the afternoon.

The yellow areas in this table indicate which subjects wore the AFS-2 ambulatory monitoring system, and their planned seat/vehicle locations. The gray areas represent days when field operations were canceled and when replacement tests were rescheduled. None-the-less, there were several field tests not replaced (e.g, due to individual workstation malfunction leading to loss of data, or vehicle malfunction leading to abbreviated tests). Vehicle 2 (perpendicular) had the greatest number of missed field tests.

Table 4. Complete Experiment Schedule and Replacement Dates

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Results:

I. Motion Sickness

All 24 soldiers reported symptoms of motion sickness to some degree during C2V operations, with 55% reporting symptoms that ranged from moderate to severe malaise (>2 points). Figure 5 shows the mean diagnostic score for all tests of each soldier.

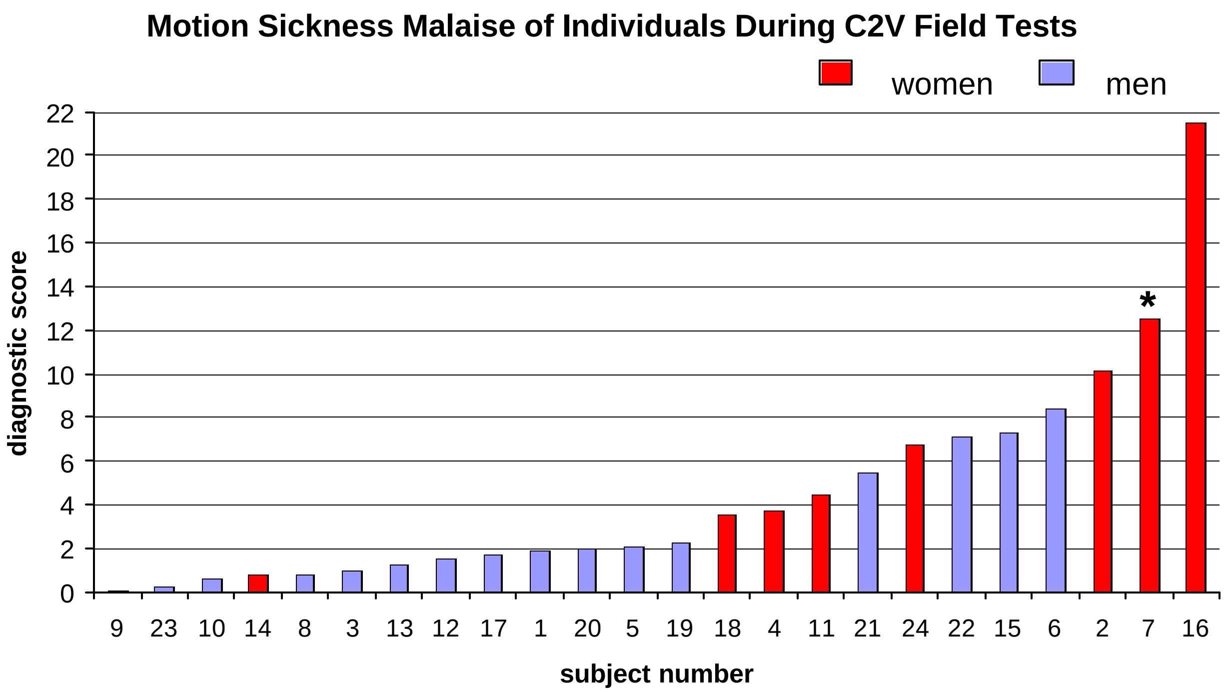

Figure 5. Malaise scores of all soldiers, averaged across vehicles, seats, and conditions.
*Subject 7 withdrew from the experiment

Motion sickness composite scores (based on a cumulative total of all symptoms) were calculated from the field test data providing 36 scores for each subject (3 vehicles x 4 seats x 3 conditions). A Friedman repeated measures ANOVA of all dependent measures was highly significant ($F=133.87$, $df=35$, $p<1.74E-10$). Wilcoxon paired tests revealed no significant differences between vehicles for the park, move, or short-halt conditions. However, there was a significant increase in motion sickness within vehicles when conditions changed from park to move (oblique, $p<0.0002$; perpendicular, $p<0.002$; and 4-forward, $p<0.00009$), and from park to short halt (oblique, $p<0.0003$; perpendicular, $p<0.005$; 4-forward, $p<0.00007$).

Figure 6 shows the mean symptom scores of subjects in each seat and vehicle across the three field test conditions. Although motion sickness scores were higher in vehicle 1, seat 3 there was no significant difference between seat 3 in any of the vehicles during the move condition. Further, there was no significant difference between seat 3 and any of the other seats in the oblique vehicle during the move or short halt conditions. It should be noted, however, that during the short halt condition, motion sickness levels were significantly higher in the oblique vehicle seat 3 than in the 4-forward vehicle seat 3 ($p<0.05$).

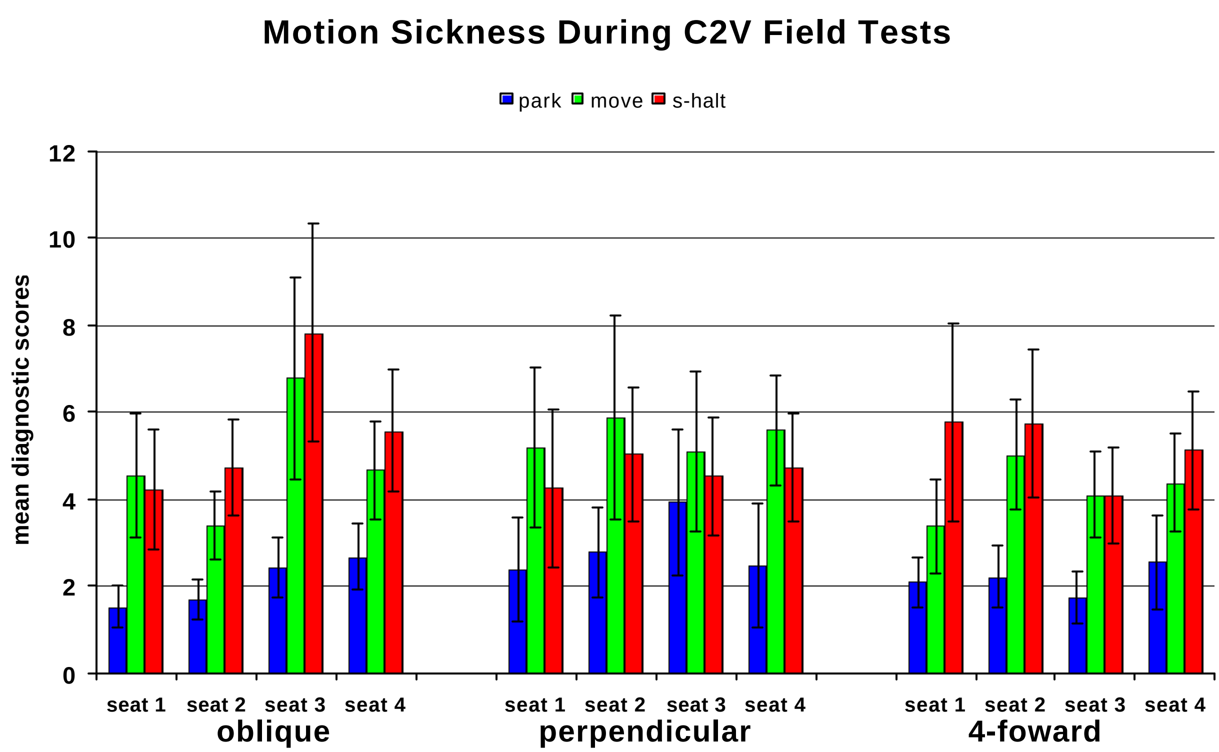

Figure 7. Average malaise scores in each vehicle and seat in park, move, and short-halt conditions (n=23).

Figure 8 below shows the specific symptoms ranked by the percentage of subjects reporting them in each of the three vehicles. Drowsiness was reported most frequently in 60-70 % of the subjects. The next most often reported symptom was headache (40-56% of subjects) followed by the sensation of increased warmth (40-45%) and nausea (35-42%). Less severe symptoms of stomach discomfort (Epigastric Discomfort, ED) and unusual awareness of stomach sensations (Epigastric Awareness, EA) were reported by at least 20% of the soldiers. Although actual vomiting episodes occurred in less than15% of the soldiers, it tended to occur repeatedly in the same individuals.

Figure 9 shows the percentage of subjects reporting drowsiness in each seat and vehicle across conditions. Inspection of this graph shows that drowsiness increased three-fold as the vehicle condition changed from park to move to short-halt. Consequently, this symptom was probably not due to sleep loss on the nights prior to field tests, (i.e., subjects arriving at the tests already drowsy).

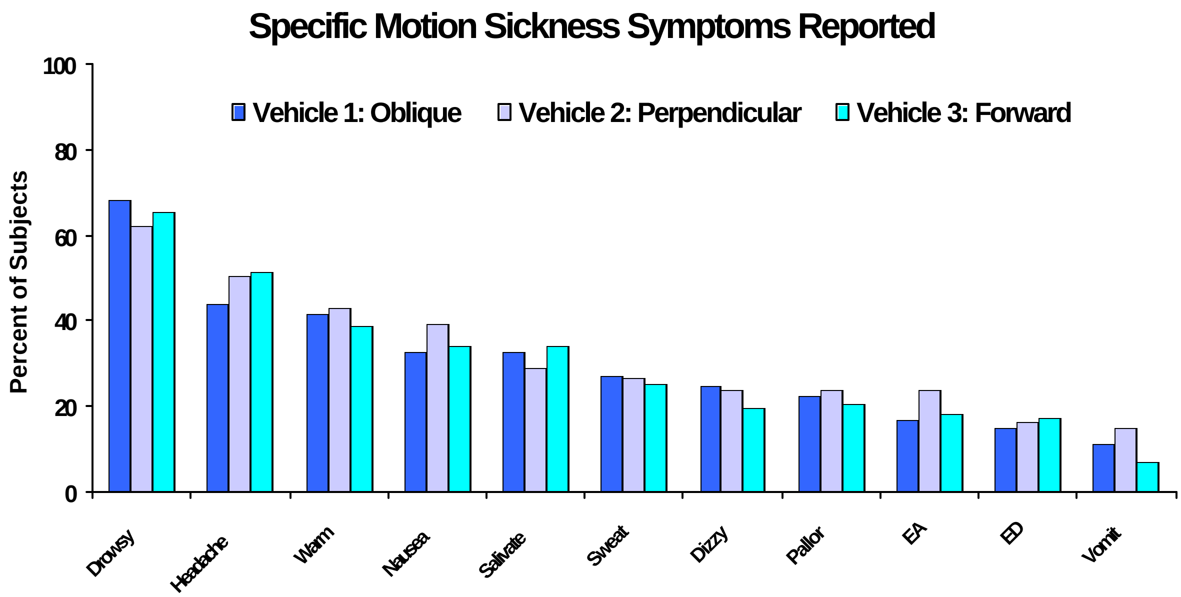

Figure 8. The percentage of subjects reporting specific symptoms during C2V field operations.

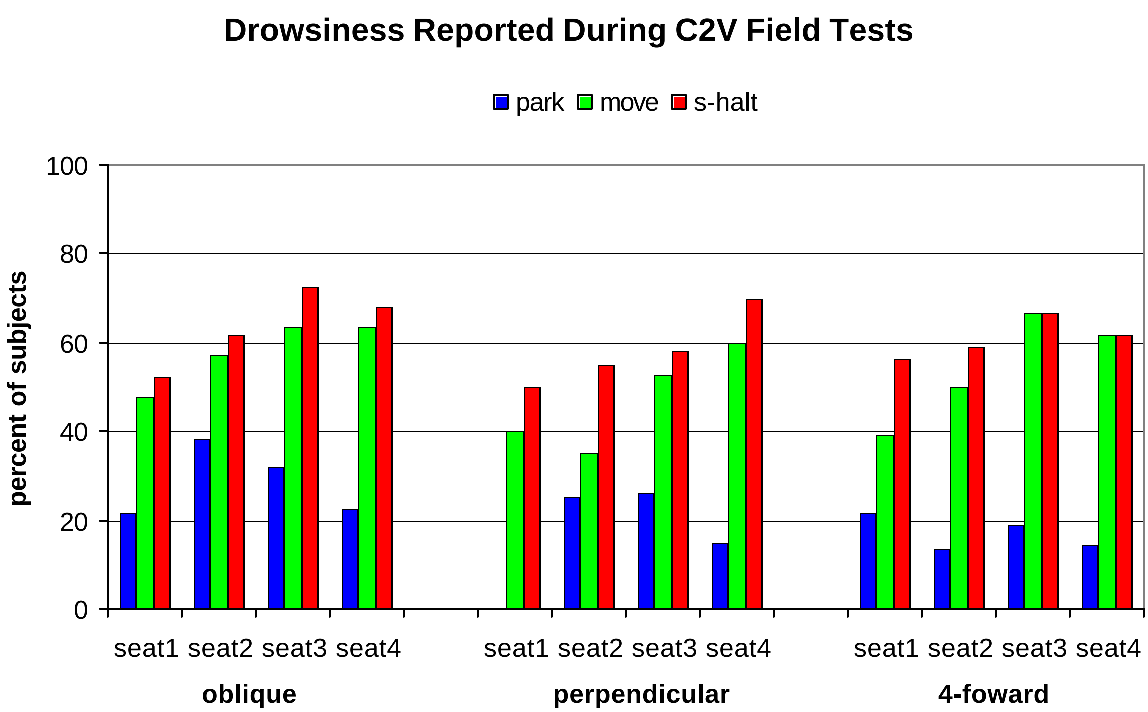

Figure 9. Percentage of subjects reporting drowsiness in each seat and vehicle across conditions in the field tests.

II. Performance

During the initial eight training trials in the classroom, all performance subtest variables of interest (accuracy, latency, errors) stabilized after one training trial with respect to subtest variance (Cochran's test for homoscedasticity of variance). All subtest variables stabilized after five sessions with respect to subtest mean (linear regression slope test, p>0.05) except for the choice reaction time mean adjusted latency, which required six sessions for stabilization. Some of the subjects reported for training sessions with significant prior night sleep loss. Attention lapses in the reaction time or grammatical reasoning subtests in these subjects were noted by the experimenter prior to knowledge of their sleep loss since they are a common symptom of the effects of sleep loss on performance (Webb 1968).

Raw performance scores were converted to z-scores for subsequent analyses. Z-scores were calculated for each subject by subtracting field test scores from the mean of all data (training, field tests, and posttest scores) and then dividing by the standard deviation. Missing data were replaced by interpolated means. A measure of composite performance was obtained by averaging z-scores across the seven subtests for each vehicle, seat and condition. Table 5 shows the summary results from ANOVA's (3 vehicles x 4 seats x 3 conditions) of performance z-scores for each subtest. The vehicle x condition and seat x condition interactions were sources of variance of most interest to the question of performance effects in the different vehicle configurations.

Table 5. ANOVA Results of Performance Subtests

		COMPOSITE	NPTAP	MANKIN	REASON
Source	**df**	**F p<**	**F p<**	**F p<**	**F p<**
Vehicle	2,44	ns	ns	7.09, 0.002	ns
Seat	3,66	3.67, 0.03	4.90, 0.007	ns	ns
Condition	2,44	44.48, 6.89E-11	29.42, 2.29E-08	7.23, 0.003	18.22, 2.00E-06
Veh. x Seat	6,132	ns	4.06, 0.002	ns	ns
Veh. x Cond.	4,88	4.87, 0.005	4.95, 0.003	3.74, 0.01	2.74, 0.04
Seat x Cond.	6,132	ns	ns	ns	ns
V x S x C	12,264	ns	ns	ns	ns
		CODSUB	**PHTAP**	**PATRNC**	**REACT3**
Source	**df**	**F p<**	**F p<**	**F p<**	**F p<**
Vehicle	2,44	8.43 0.001	Ns	ns	57.9, 3.01E-12
Seat	3,66	ns	10.84, 0.00003	ns	ns
Condition	2,44	20.53, 0.00001	32.73, 3.95E-09	ns	11.84, 0.0001
Veh. x Seat	6,132	ns	ns	ns	ns
Veh. x Cond.	4,88	ns	ns	ns	ns
Seat x Cond.	6,132	ns	2.54, 0.03	ns	ns
V x S x C	12,264	ns	2.29, 0.03	ns	ns

The vehicle x condition interaction was significant for the non-preferred hand tapping (NPTAP), spatial transformation (MANKIN), grammatical reasoning (REASON), and the composite (mean of all tests). Table 6 below shows the results of post-hoc comparison tests (Tukey's HSD).

Table 5. Tukey's HSD Multiple Comparisons of Vehicle x Condition

Park vs. Move			
	Oblique	**Perpendicular**	**4-Forward**
COMPOSITE	$p<4.05E-06$	$p<2.26E-06$	ns
NPTAP	$p<2.32E-06$	$p<2.26E-06$	ns
MANKIN	ns	$p<0.002$	ns
REASON	ns	$p<0.00008$	ns
Park vs. Short-halt			
COMPOSITE	$p<0.004$	$p<0.03$	ns
NPTAP	$p<0.0001$	ns	ns
MANKIN	ns	ns	ns
REASON	ns	ns	ns
Move vs. Short-halt			
COMPOSITE	ns	$p<0.002$	ns
NPTAP	ns	$p<0.02$	ns
MANKIN	ns	ns	ns
REASON	$p<0.003$	ns	ns

A surprising result showed that the composite performance scores of soldiers did not degrade significantly in vehicle 3 (4-forward) between conditions. However, further analyses revealed that that the composite score was heavily weighted by only 3 of the 7 subtests. NPTAP did not degrade across any of the conditions in the 4-forward vehicle, nor in the comparison of Move vs. Short Halt in the oblique vehicle, or between Park vs. Short-halt in the perpendicular vehicles. Similarly, REASON showed no significant decrement in vehicle 3 (4-forward) between conditions, nor was it degraded in vehicle 1 (oblique) during the Park vs. Move or Park vs. Short-Halt. And in vehicle 3 (perpendicular), although there was a profound decrement in this performance metric in the Park vs. Move comparison, this decrement was not significant during the Park vs. Short-Halt or the Move vs. Short-halt conditions.

These results indicate that the soldiers' ability to perform this task improved when the vehicle stopped. Interestingly, only the MANKIN task actually showed a general trend of improvement throughout the course of field tests with a significant decrease in this metric occurring only in the perpendicular vehicle during the Park vs. Move comparison.

The interaction seat x condition interaction was only significant for the preferred hand-tapping subtest (PHTAP). Post-hoc tests showed that this performance metric was significantly degraded in all seats ($p<0.02$ or lower) except for seat 4, the one situated closest to the front and which always faced forward in all vehicles. Further, only PHTAP was significant for the vehicle x seats x condition interaction. Post-hoc tests showed that only in seat 1 (most rear) in the oblique vehicle was this task significantly degraded, and only during the Short-halt condition ($p<0.01$ or lower).

Two methods for describing the degree of performance decrement observed in this experiment were used. The first was based on a percent change from baseline scores. Baseline scores for each subtest for each subject were computed as the average of the last training session (trial 8) performed in the classroom prior to the start of field tests and the post-field test session conducted at the end of the experiment. These baseline scores were computed to establish an approximate baseline to accommodate practice effects, which modulated performance, levels during the field test batteries. These practice effects occurred during the course of 29-84 repetitions of the performance test batteries performed by the soldiers. Due to the differing number of test batteries performed in the C2V, performance improvement from training trial 8 to the post-filed test day ranged from 1.4% to 43.7%. Figure 9 shows percent performance changes for the composite scores and each for subtests observed in all seats, vehicles and across field test conditions.

Performance decrements were evaluated for potential operational significance by establishing a subject impairment index and Blood Alcohol Level dose equivalency (BAL%) based on the percentage of baseline scores. The subject impairment criterion was defined as at least a 5% performance decrement (negative percent change) in at least 5 of the seven performance battery subtests (Turnage & Kennedy, 1992). The probability of at least 5 subtest exceeding this criterion is $p<0.02$, based upon a Monte Carlo simulation of performance subtest changes using performance data obtained from a prior human study (Cowings, et. al 1996). This impairment occurred in nearly half (11 of 24) of the participating soldiers. A performance decrement >5% was observed in 22 of the 24 subjects for at least two subtests and in more than 20 subjects for at least three subtests (see figure 10).

The second operational impairment index involved the conversion of performance percent subtest decrements to BAL%. Data from a study of performance subtest responses to alcohol levels from 0.0 –0.15 BAL% (Kennedy, Turner & Wilkes, 1993), were converted from number of correct responses to percent net accuracy change for each subtest common to both studies. Linear regression on percent subtest change against BAL% was then performed for BAL% from 0.0-0.05% and from 0.05-0.15%. The obtained regression coefficients were then used to convert percent decrement for each subtest in this study to BAL%. To establish the regression coefficients for the composite performance metric, the percent decrements for each subtest at each BAL% in the Kennedy study were weighted by the variance explained by linear regression (F ratio), and the weighted mean decrements were then used to establish the regression coefficients for composite performance. We established two BAL% impairment criteria for the observed performance decrements: BAL%>0.08, which is the legal definition of impairment in most American states

(Dement, 1997), and BAL%>0.025, which is the minimum level found to be associated with significant operational performance errors (Billings, et al., 1991).

Performance Changes During C2V Field Tests

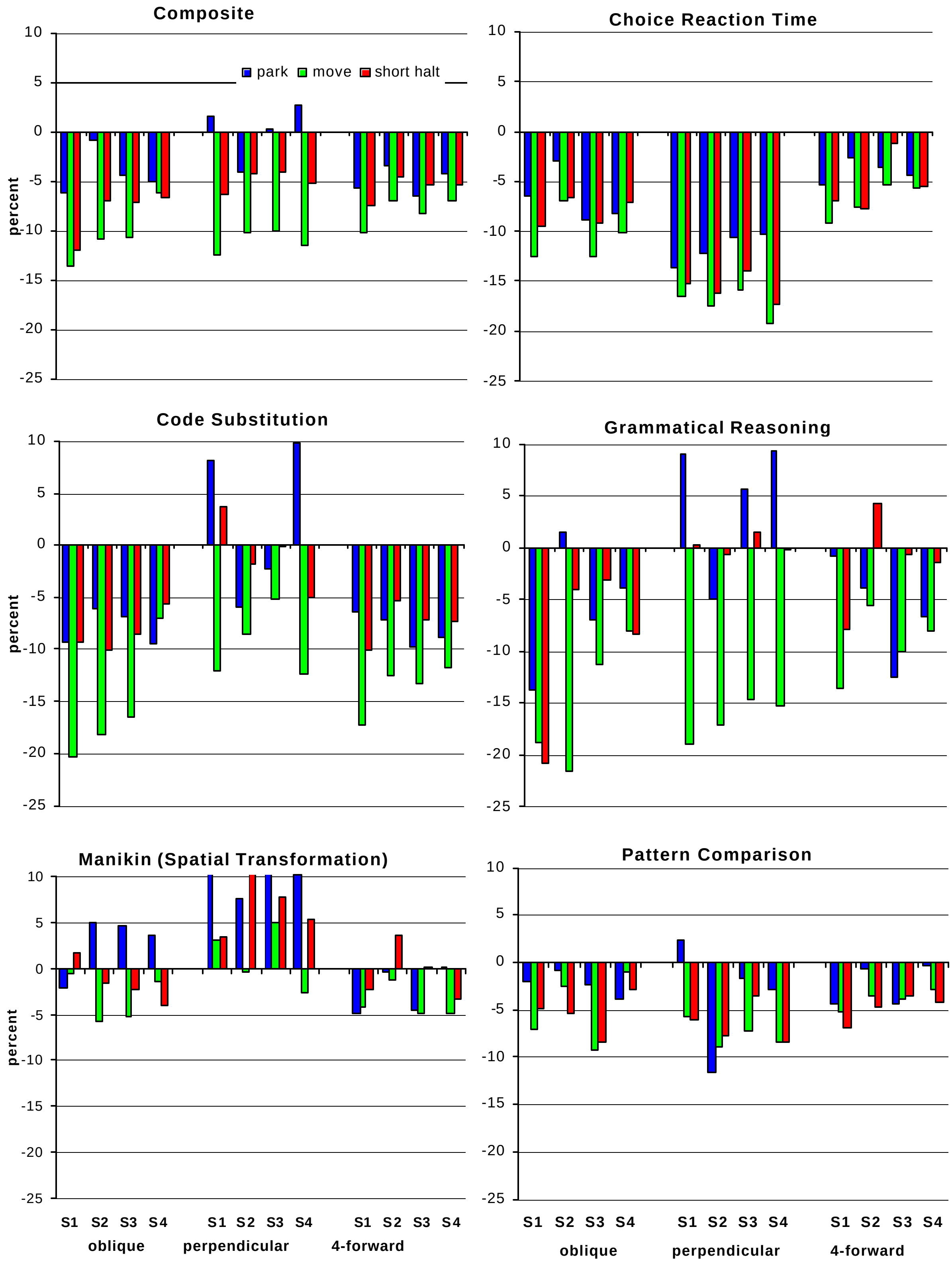

Figure 9. Performance percentages expressed as changes from baseline for all subtests. Labels on the x-axis (s1-s4) represent seats 1-4.

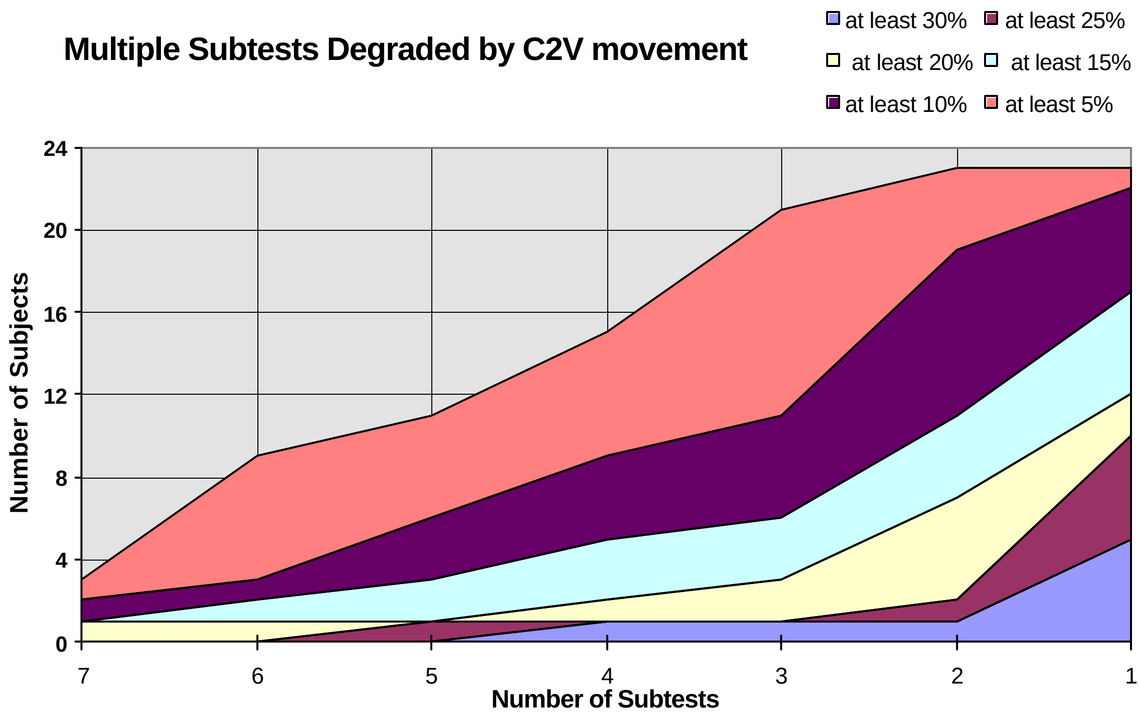

Figure 10. Number of subjects showing degraded skills of 5% to 30% on one to seven of the performance subtests

Figure11 below shows blood alcohol level equivalency scores (BAL%) of subjects during park, move, and short halt conditions. Eight subjects showed BAL% levels of >0.08 during the move conditions while 19 of 23 subjects showed a BAL% of >0.025 during this condition. Table 6 below indicates the individual subjects ranked for percent performance changes and comparable BAL%

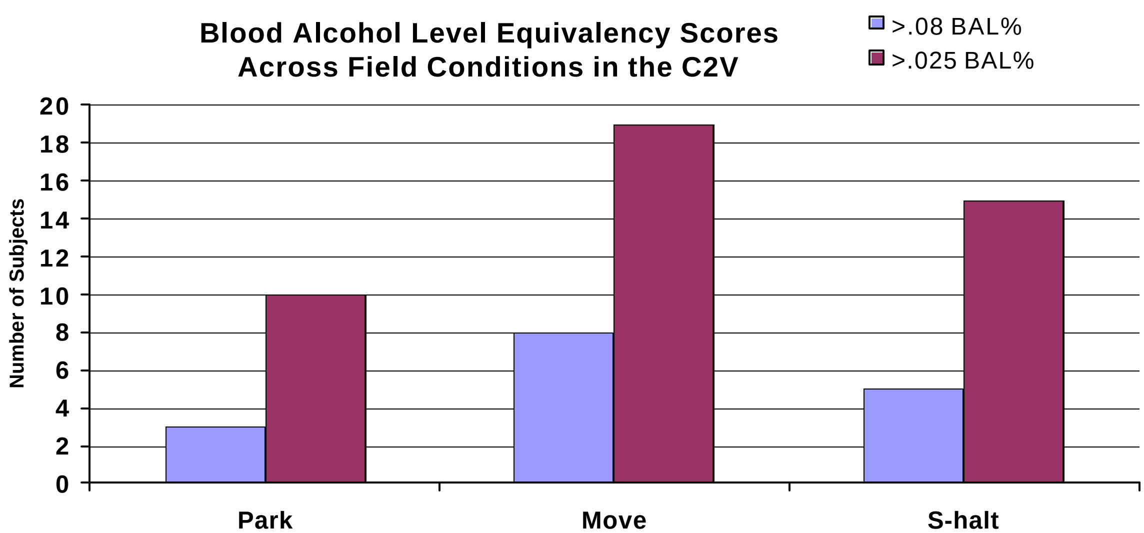

Figure 11. Number of subjects with BAL% scores of >0.08 and >0.025 during field test condition

Table 6. Individuals Ranked by Percent Performance Changes as BAL%.

SUBTEST MEAN PERCENTAGES FROM BASELINE				BAL% EQUIVALENCE			
Subject	Park	Move	S-halt	Subject	Park	Move	S-halt
4	9.61	0.45	3.85	**4**	0.000	0.000	0.000
12	8.73	6.99	3.93	**12**	0.000	0.000	0.000
19	10.42	4.84	7.66	**19**	0.000	0.000	0.000
17	1.28	-0.79	2.46	**17**	0.000	0.008	0.000
11	5.21	-3.03	1.95	**11**	0.000	0.031	0.000
2	3.49	-3.52	3.76	**2**	0.000	0.036	0.000
5	-0.60	-3.69	-3.71	**5**	0.006	0.038	0.038
8*	-5.20	-4.06	-1.98	**8***	0.052	0.041	0.020
1	3.86	-5.08	-5.31	**1**	0.000	0.051	0.053
18	-3.29	-5.19	-5.74	**18**	0.034	0.052	0.055
9	-3.01	-5.32	-2.94	**9**	0.031	0.053	0.030
21	2.41	-6.97	-3.69	**21**	0.000	0.062	0.038
10	-2.88	-8.51	-6.18	**10**	0.029	0.071	0.058
20	-0.62	-8.81	0.52	**20**	0.006	0.073	0.000
6	5.87	-8.86	-8.53	**6**	0.000	0.073	0.071
15	-4.29	-10.53	-5.36	**15**	0.044	**0.083**	0.053
13	0.32	-11.66	-4.53	**13**	0.000	**0.089**	0.046
3	1.85	-11.98	-6.73	**3**	0.000	**0.091**	0.061
24	-5.74	-15.39	-10.54	**24**	0.055	**0.111**	**0.083**
23	-6.00	-15.64	-18.08	**23**	0.057	**0.113**	**0.127**
22	-10.13	-17.70	-11.33	**22**	**0.081**	**0.124**	**0.088**
14	-15.80	-20.89	-11.98	**14**	**0.113**	**0.143**	**0.091**
16	-20.43	-32.62	-25.24	**16**	**0.140**	**0.211**	**0.168**

- Grammatical reasoning results deleted for subject 8 due to anomalies in his data.

III. Mood and Sleep

The Activation Mood Dimension (i.e., readiness to perform) indicates a state of vigor, energetic arousal, or bodily reactivity in which changes in arousal are associated with changes in energy levels. The Affective Mood Dimension (i.e., self-perception of readiness) reflects feelings or emotion associated with a mental state in which changes in arousal are associated with changes in psychological tension. Figure 12 shows the mood scores for both the activation and affective dimensions in each vehicle and seat across test conditions. Higher scores reflect more positive mood states.

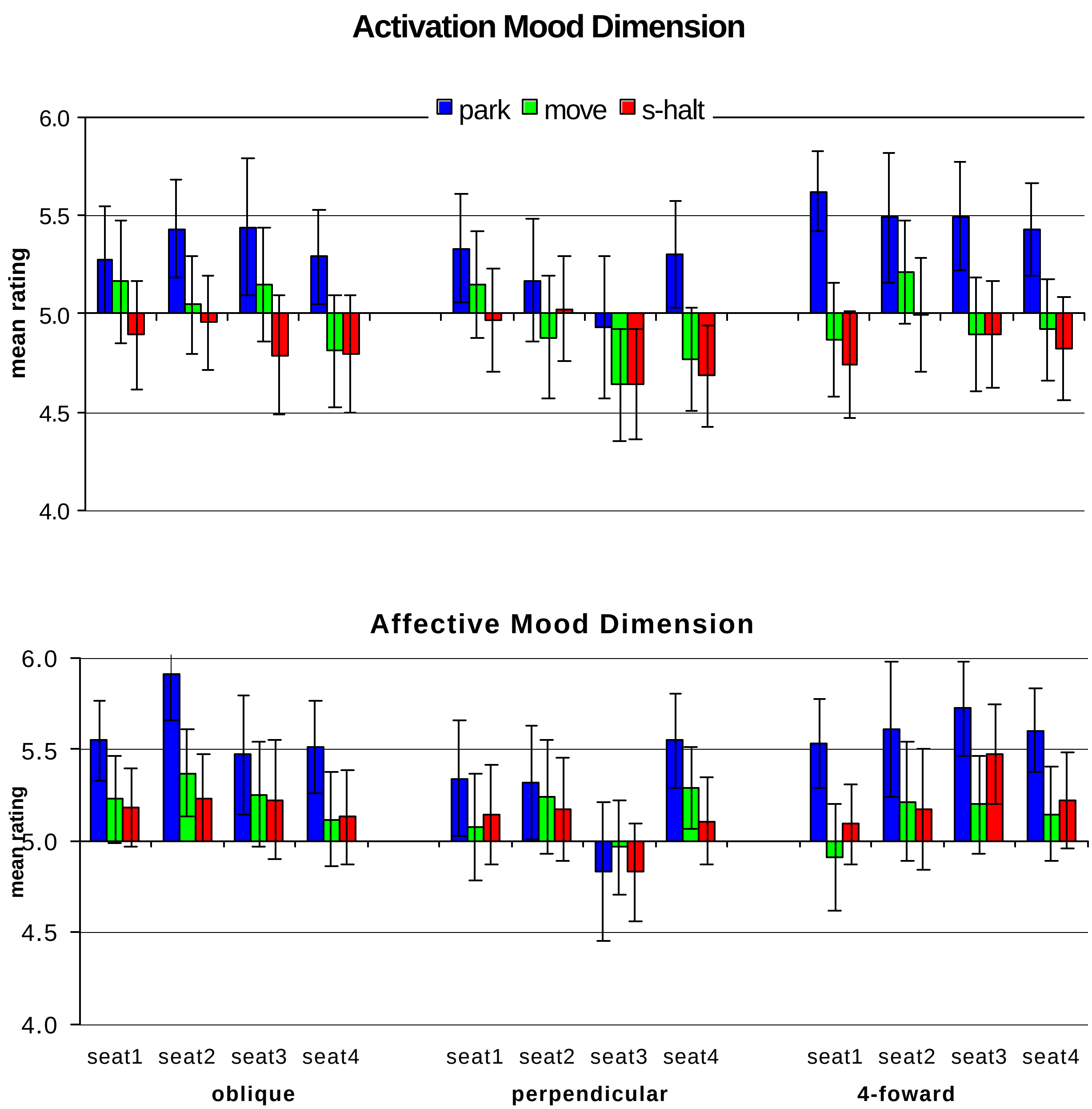

Figure 12. Activation and affective mood dimensions across field test conditions (n=23).

Mood ratings measured during the field tests provided 36 scores for each subject (3 vehicles x 4 seats x 3 conditions). Friedman ANOVA's for the activation and affective dimensions were both highly significant, (F=102.29, df=35, p<1.63E-08, and F=88.23, df=35, p<1.73E-06, respectively). It is clear from inspecting figure 12 that both mood dimensions showed a progressive deterioration across field conditions. To examine specific differences between vehicles and seats, relative to Park, Move and Short-halt conditions, subsequent Wilcoxon paired tests were performed. For activation scores there were generally significant decreases (p<0.01) from Parked to Move and Parked to Short-halt. The only exceptions were the rear two seats (seats 1 and 2) in the perpendicular vehicle, which may be related to the lower initial levels observed in the Parked condition. For affective scores, there was again a general decline across field conditions. However, this dimension showed fewer significant changes than the activation dimension. Scores were generally lower in the perpendicular vehicle in the parked condition relative to the other two vehicles. As a result, only seat 4 showed a significant decrease from parked to short-halt. In the oblique vehicle, only seat 3 showed no significant change across conditions, while in the 4-forward vehicle, all seats showed a significant decrease ($p<0.05$) when vehicles changed conditions. Figure 12 shows each of the mood states that comprise the two mood dimensions.

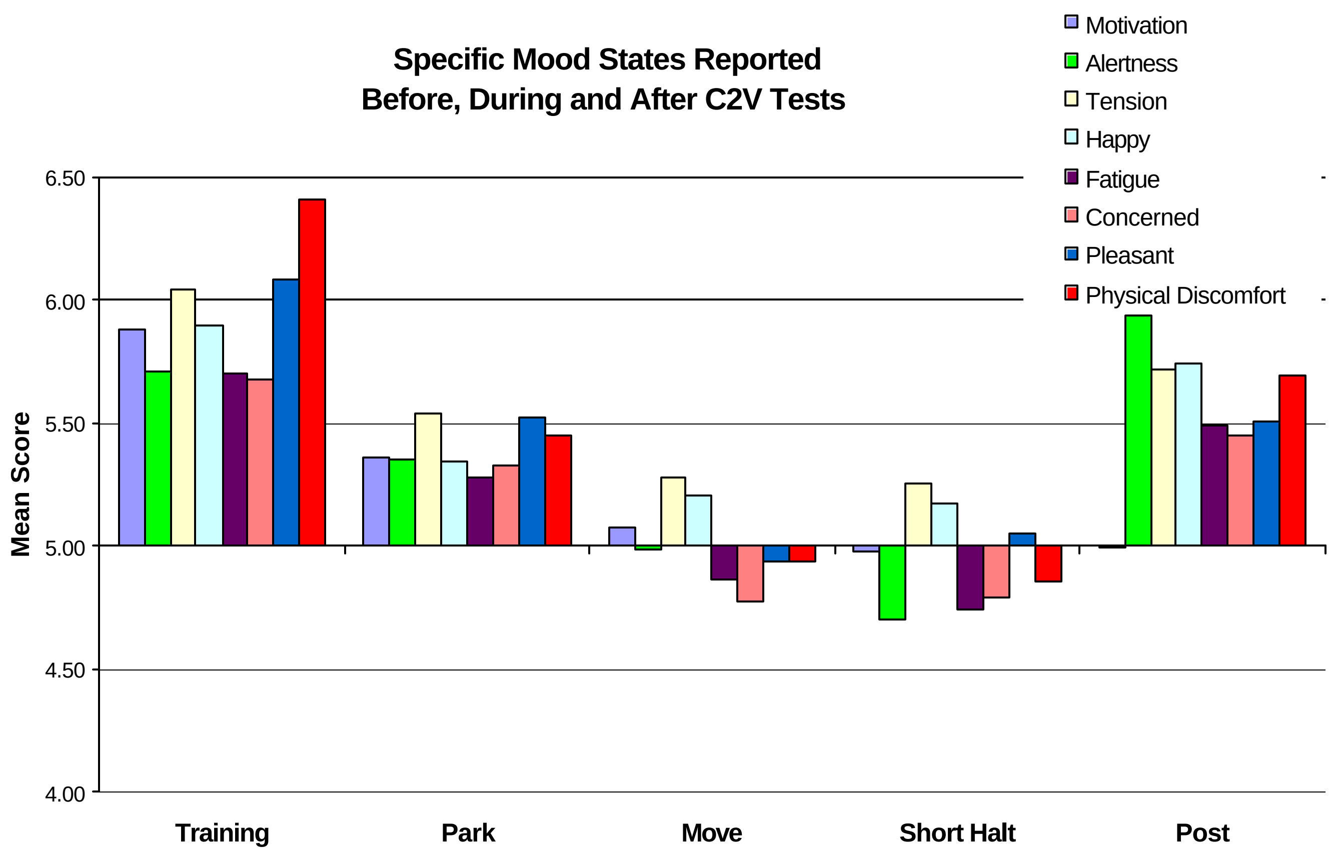

Figure 12. Mood scores of the last day of training compared to three field conditions and a classroom test at the end of the experiment

In the present study, there were three measures of sleep: (1) the number of hours of sleep obtained on the previous night before each C2V field test; and two questions that documented the quality of sleep, (2) "trouble falling asleep" and (3) "number of waking episodes on the previous night".

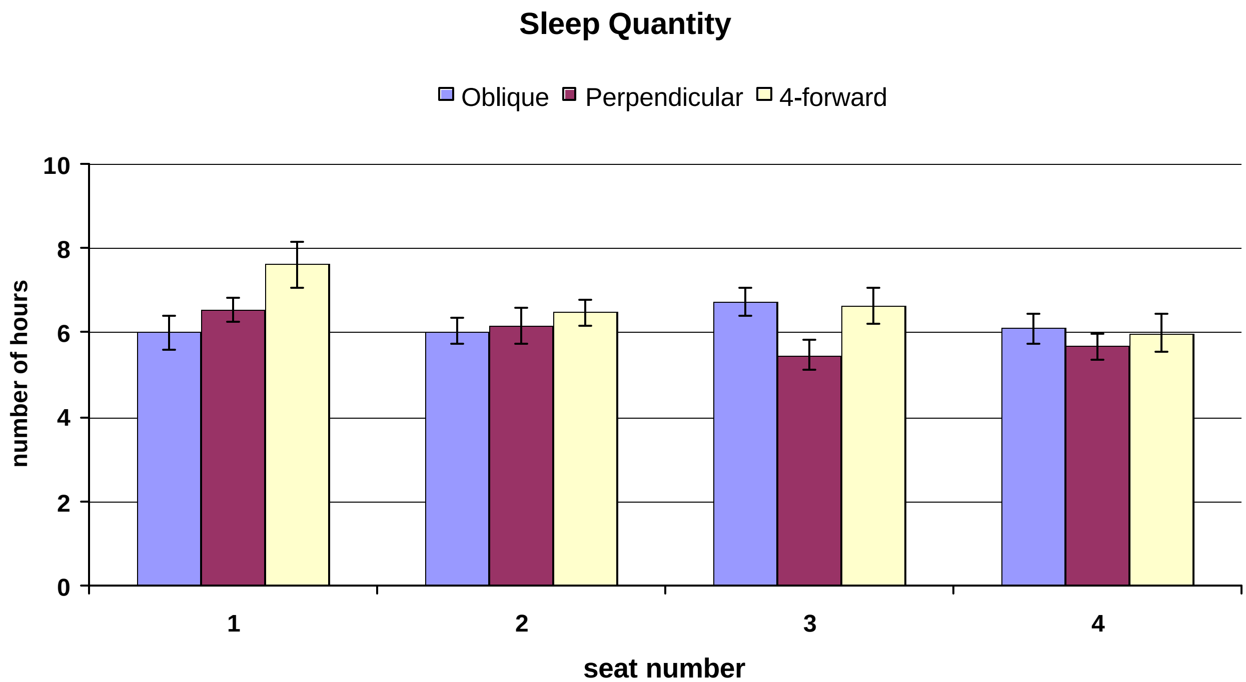

Figure 13. Sleep duration reported on the night before C2V field tests (n=23)

The mean sleep duration reported during the field exercises was 6.3 hours per night, which ranged from 1.5 to 16 hours. An ANOVA on sleep duration was performed to determine if this might be related to observations of performance decrements relative to specific vehicles and seats. The vehicle x seat interaction was significant ($F=2.93$, $df=6,132$, $p<0.03$), however, post-hoc comparisons did not reveal any significant differences within or between vehicles for each seat. Trouble falling asleep and the number of wakings reported on the previous night were analyzed and these variables showed no significant effects for vehicles and seats.

The one exception was subject 15 who reported only 1.5 hours of sleep prior to his test in the perpendicular vehicle (seat 3). On the previous night this subject reported maximal trouble falling asleep (mood/sleep scale score =0.0), and the maximum number of awakenings (at least 6). On this test day, subject 15 responded with the maximum performance and activation mood dimension decrements recorded from all subjects and test batteries in this study. Composite performance showed a decrement of –33.5%, equivalent to a BAL% of 0.22%. All seven subtests exhibited decrements of at least –25.6%, greatly exceeding the minimum impact of –5% for 5 of 7 subtests known to effect operational efficiency (Turnage & Kennedy, 1992).

IV. Physiological Responses

Physiological data during field exercises were recorded on analog cassette tapes. Data from these tapes were digitized and processed on a Concurrent computer with custom software. These data were then edited to remove artifact and reduced to 15-second averages for each physiological channel. Time code recorded on analog tape was used to select specific epochs that corresponded to the C2V field test conditions of park, move and short-halt. Physiological data were collected only on the soldiers in seat 1 and seat 3 of each vehicle. Missing data for each subject was replaced with interpolated means before statistical analyses. Figure 14 shows the changes in physiological response means across vehicles, seats and conditions. Summary results from ANOVA (3 vehicles x 2 seats x 3 conditions) are described in Table 7. Sources of variance of most interest in this study were the main effect for condition and the interactions of vehicle x condition and seat x condition.

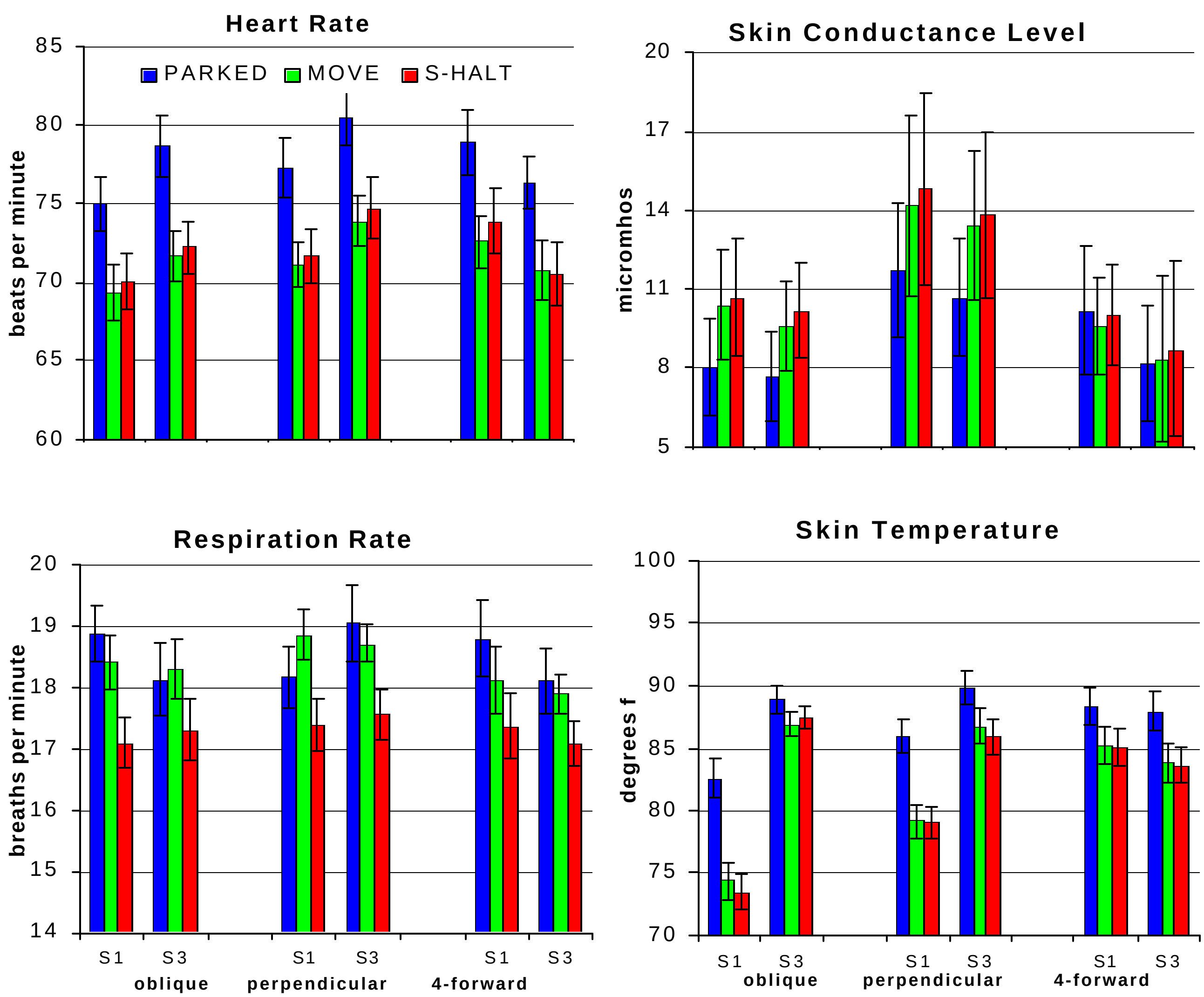

Figure14. Means and sem of physiological responses during C2V field tests (N=23)

Table 7. Summary ANOVA Results of Physiological Response Means

		Heart Rate		Respiration		Skin Conductance		Temperature	
Source	**df**	**F**	**p<**	**F**	**p<**	**F**	**p<**	**F**	**p<**
Vehicle	2,44	ns		ns		ns		6.20	0.005
Seat	1,22	ns		ns		ns		51.95,	3.18E-07
Condition	2,44	31.51,	3.16E-07	17.83,	0.00005	4.85,	0.03	44.8,	3.94E-07
Veh. x Seat	2,44	4.05,	0.02	ns		ns		20.15,	1.83E-06
Veh. x Cond.	4,88	ns		ns		ns		ns	
Seat x Cond.	2,44	ns		ns		ns		16.73,	0.00004
V x S x C	4,88	ns		3.53	0.01	ns		7.13,	0.0007

The main effect for condition was significant for all four physiological response means. Post-hoc comparisons (Tukey's HSD) of the park vs. move conditions were significant for heart rate ($p<0.006$), and skin temperature ($p<0.003$). Comparisons for park vs. Short halt were significant for heart rate ($p<0.01$), respiration rate ($p<0.001$), and skin temperature ($p<0.001$). The comparison for move vs. Short halt was significant only for respiration rate ($p<0.004$). Inspection of figure 14 shows that heart rate decreased during the change from park to move and remained low during the short halt conditions. Respiration rate also tended to decrease from the park condition but was only significantly lower than park during the short-halt. Skin temperature, like heart rate, decreased from the park to move and remained low during short halt. Post-hoc comparisons for skin conductance level were not significant.

The vehicle x condition interaction was not significant for any variable, and only skin temperature was found to be significant for the seat x condition interaction Post-hoc comparisons of .this measure showed that the decrease in temperature from the park condition was greater in seat 3 (rear) than in seat 1 during the move ($p<0.0003$) and short halt ($p<0.005$)

The accelerometer transducer, worn on the soldier's helmet measured velocity and force (movement in three different axes) with respect to field test conditions. This variable was used to confirm that epochs selected correctly corresponded to the movement profile of the C2V field tests, and to determine if there were differences between seats and vehicles. ANOVA was performed on the x-axis only, as the other two axes (y and z) were comparable. Only the main effect for conditions was significant ($F=148.29$, $df=2,44$, $p<9.99E-16$). Post-hoc comparisons of conditions were all significant ($p<0.00001$).

A second metric used to characterize physiological changes was the coefficient of variation (standard deviation / mean), for each response. The coefficient of variation provides a measure of response variability across field conditions. Figure 15 shows these data for each seat, vehicle and condition.

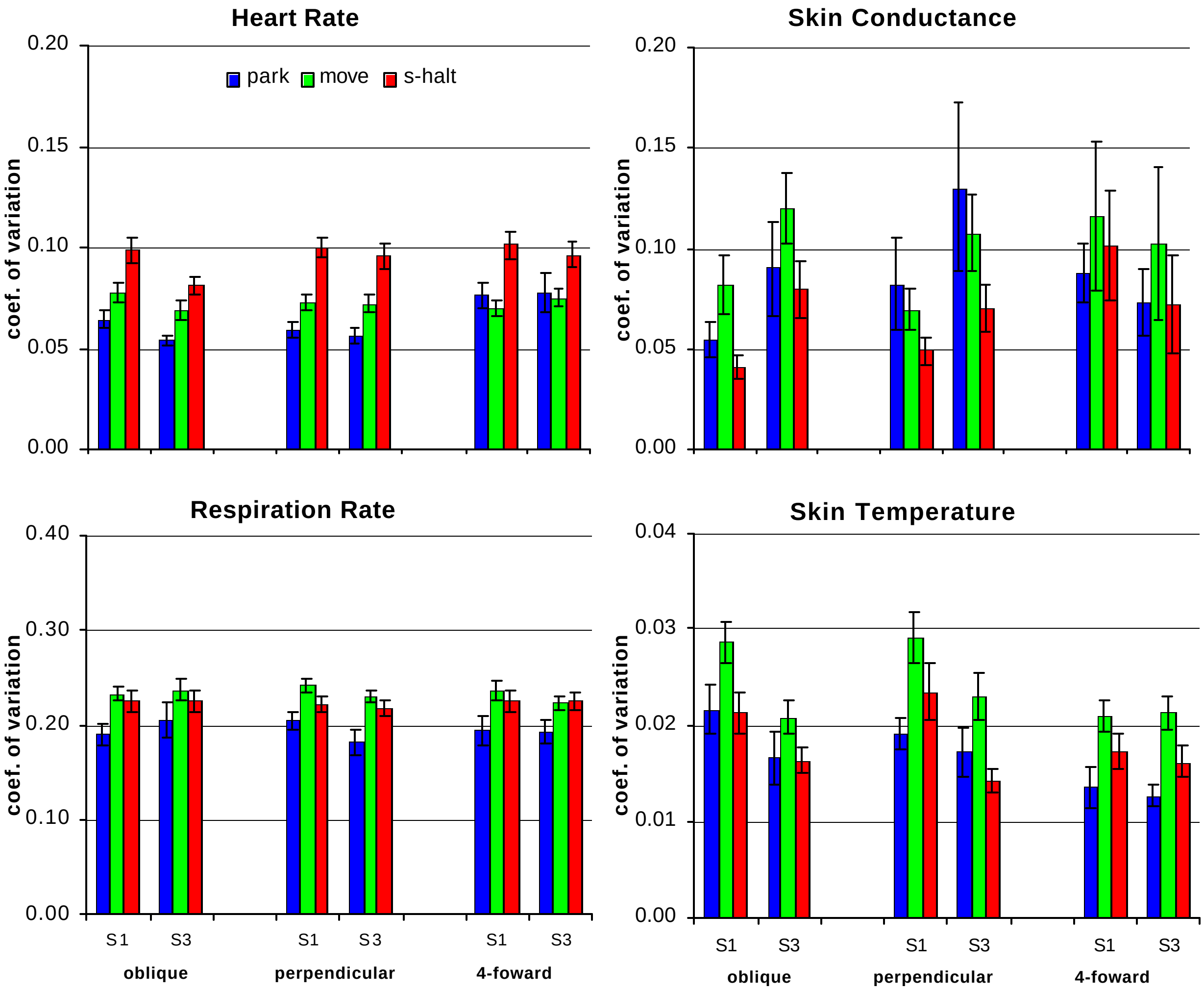

Figure 15. Physiological response variability, expressed as the coefficient of variation, across vehicles, seats and conditions.

Table 8. Summary ANOVA Results of Physiological Response Coefficient of Variation

		Heart Rate		Respiration		Skin Conductance		Temperature	
Source	**df**	**F**	**p<**	**F**	**p<**	**F**	**p<**	**F**	**p<**
Vehicle	2,44	4.20,	0.03	ns		ns		5.22	0.01
Seat	1,22	11.48,	0.002	ns		ns		22.44,	0.0001
Condition	2,44	77.65,	3.16E-10	38.42,	2.17E-09	ns		21.19,	4.19E-07
Veh. x Seat	2,44	ns		ns		4.58,	0.02	ns	
Veh. x Cond.	4,88	5.64,	0.002	ns		ns		ns	
Seat x Cond.	2,44	ns		ns		ns		ns	
V x S x C	4,88	ns		ns		ns		ns	

The main effect for condition was significant for all variables except skin conductance. Post-hoc comparisons (Tukey's HSD) of the park vs. move conditions were significant for respiration rate ($p<0.0003$), and skin temperature ($p<0.0001$). Comparisons for park vs. short halt were significant for heart rate ($p<0.00001$), and respiration rate ($p<0.01$). The comparison for move vs. short halt was significant for heart rate ($p<0.0005$), and skin temperature ($p<0.001$). Inspection of figure 15 shows that variability of the heart rate response increased during the change from park to move and continued to increase during the short halt conditions. Respiration rate variability also tended to increase from the park condition with only a slight decrease (not significant) during short-halt. Skin temperature variability, similarly increased from the park to move and then decreased again during short halt. The vehicle x condition interaction was only significant for heart rate, however, the post-hoc comparisons between vehicles for each condition were not significant.

It is well known that physiological responses to stressful stimuli are highly idiosyncratic; where some subjects show larger magnitude responses in one variable than another (Engel, 1972; Cowings, et al., 1986; Cowings, Naifeh, and Toscano, 1990; Stout, Toscano and Cowings, 1993). Continuous physiological monitoring during the 4-hour field tests provided more information about environmental impact on crew than was possible from measurements taken at discrete intervals. These data reflect immediate responses to changes in environmental conditions and the time-course of both onset and recovery from stimulation. Figure 16 shows the physiological data of six soldiers expressed as one-minute contiguous averages. This graph illustrates individual differences in autonomic responsivity.

The graph on the left shows the data of three soldiers from one field test who showed consistently "good " overall performance during this experiment. The figure on the right shows three soldiers, selected for consistently 'poor" overall performance. The keys of this graph show the composite performance percent change and averaged symptom scores of each subject on this specific test day. The colored bars on the x-axis at the bottom of these charts represent the approximate periods of the initial park (blue), move (green), and short-halt (red) conditions. It is noted that these are only approximations, as the duration of these field conditions varied widely from day to day. On average, park and short-halt periods were 10-15 min in duration, while move conditions varied from 30 to 50 minutes. The specific tests shown here were selected because they were: representative of the specific subject's physiological response profiles throughout C2V field tests, contained complete performance, mood and diagnostic data, and were not interrupted by vehicle or computer malfunctions.

Inspection of figure 16 shows that subjects with poor performance had higher heart rate levels and greater variability on all parameters than the good performers. Also it is apparent that relatively large changes, particularly in skin temperature, occurred as field conditions changed. Subject 14, who reported only slight motion sickness symptoms during this test but whose performance was consistently poor shows physiological responses patterns similar to the two other subjects with poor performance and severe motion sickness. Either subject 14 was reporting symptoms incorrectly or was unaware of his/her physical reaction to environmental changes.

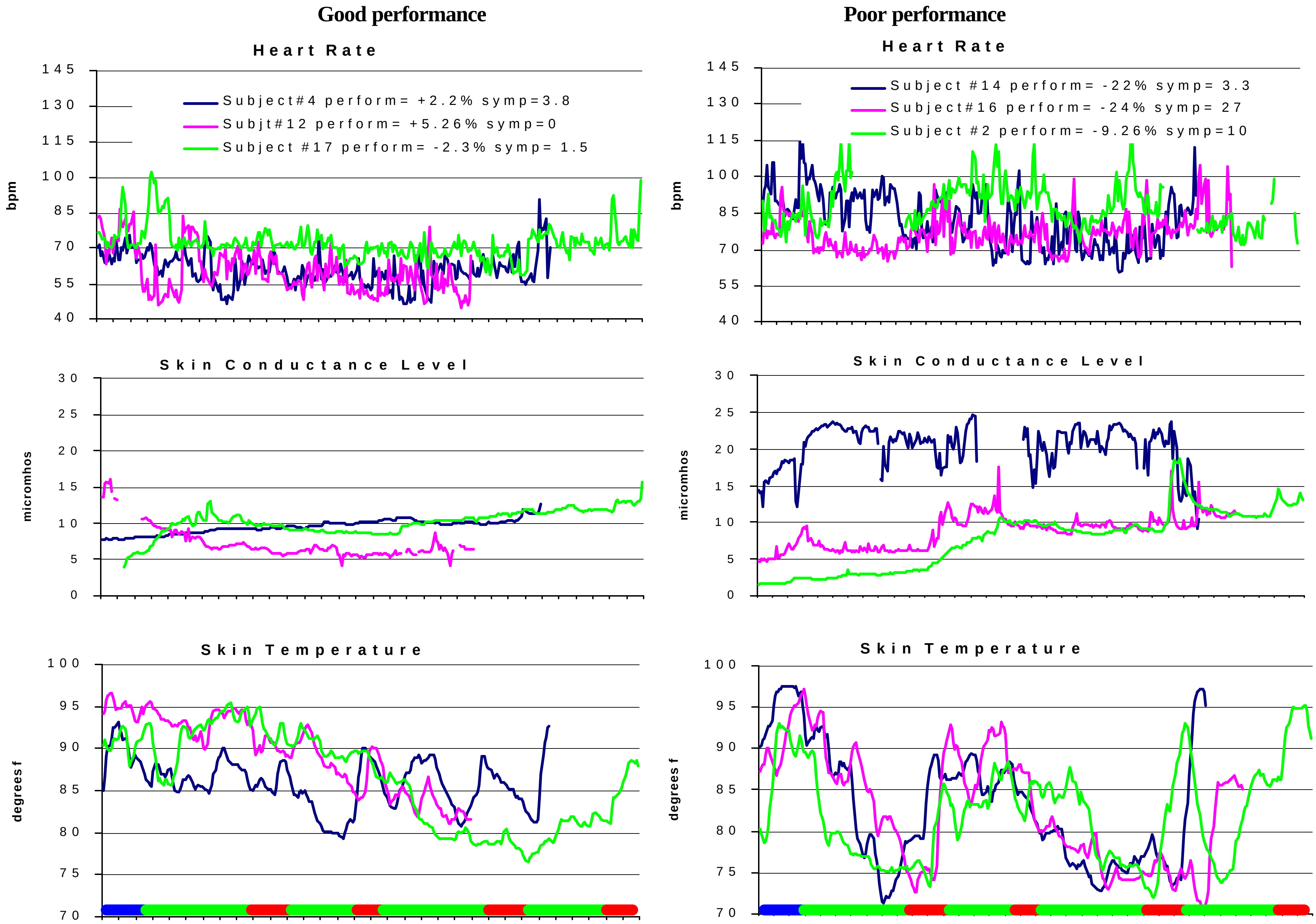

Figure 16. Physiological responses to C2V conditions. Color bar on x-axis: park (blue), move (green) and short-halt (red).

Discussion:

The primary question addressed by this investigation was to determine the effects of C2V seat configuration during mobile field operations on incidences of motion sickness and on the ability of soldiers to perform cognitive and psychomotor tasks. The methodology of converging indicators, which included performance variables, mood state scales, symptom reports, and physiological responses, has been found to increase the accuracy of the assessment of motion sickness (Stout and Cowings, 1993). This approach likewise, proved successful in the present study as it provided multiple indicators of both subjective and objective effects of environmental impact on soldier functional state.

Motion sickness was reported by all subjects with symptoms ranging from slight to severe. Although only 15% of the participants experienced actual vomiting, results indicated no statistical differences between vehicles and seats, but in all cases, symptom levels increased as conditions changed from park to move to short-halt. Drowsiness, the most frequently reported symptom, increased significantly across the field conditions. Although there was some drowsiness reported in the initial park condition, it was apparently unrelated to the previous night's sleep.

The diagnostic scale employed in this study was developed by a US Navy research group (Graybiel,) and has been used extensively by researchers in this field (Cowings, Crampton,). It consists of easy to understand questions regarding specific symptoms experienced, which are later subjected to a standardized scoring method allowing comparisons across many studies and environmental conditions. It is, none-the-less, a subjective scale, which depends heavily on the accuracy of initial reports. In most research environments, the subject's report is complemented by simultaneous observations by a trained investigator. Such symptoms as "pallor' for example, require that another person observe the subject to provide this metric. In the present study, no observer trained in this assessment scale participated. Further, the levels of symptoms reported may have been inconsistent, with some subjects "over reporting" (e.g., subject 16) and others "under-reporting" symptoms (e.g., subject 14). The latter may have been the result of insufficient training some of the test participants during the pre-test classroom instruction period. These training issues may be corrected future studies.

Despite these factors, however, the frequency of specific symptoms reported and timing of their occurrence within the field test operations are consistent with the conclusion that motion sickness did occur and that symptom incidences and severity were related to C2V test conditions. This finding is consistent with the literature on the etiology of motion sickness as a function of sensory conflict (Reason and Brand, 1975).

Performance analyses also revealed no substantial differences between vehicles and seats within vehicles. The composite performance was not significantly degraded in vehicle 3 (4-forward) but this was largely influenced by only 3 of the 7 subtests. Calculation of BAL%, used as an index of relative impairment showed that 19 of 23 subjects were >0.025% and 8 of 23 were >0.08% during the move conditions in the C2V field tests.

Unlike the symptom scale, performance metrics provide a more objective means of assessing environmental impacts on individual functional state, with proven validity and reliability (Kennedy). The Delta performance battery employed in the present study has been shown in several studies to reliably predict military operational performance (Turnage and Kennedy, 1992Bliss, 1990; Hodgson and Golding, 1991). Training data obtained during pre-test classroom instruction and cohort analysis indicated that the training process was reliable and that there were no consequential differences between the Ft. Hood soldiers and other groups previously tested.

The number of performance batteries completed during the C2V field tests ranged from 31 to 86 trials resulting in differing amounts of practice for test participants. The reliability of the percent decrements reported were dependent on the reliability of baseline performance. Baseline, in this study, was the mean of the last training trial in the classroom and the post-field test classroom trial. These decrements reported, therefore, require further validation following mathematical detrending of the individual practice effects for each subtest. Despite the lack of detrending performed thus far, it is noted that all subjects were found to have reached a training performance plateau after only 8 sessions of the pre-test classroom sessions. Further, z-score calculations used in statistical analysis of performance changes were based on all scores of all subjects collected throughout the experiment.

Performance decrements associated with different BAL% levels were established by Kennedy (Kennedy, et al, 1993) and were employed in our own research on performance effects of promethazine (Cowings, et al., 1996). However, the BAL % conversion formulas used in the 1986 study were based on a double blind design with placebo controls, which were not available in the present study. Further earlier tests were based on the DELTA precursor test battery (Automated Portable Tests System), which was presented on a different platform. As such, evaluating subject impairment in terms of BAL% in the present study is somewhat speculative. However, subject 16 in the present study showed a mean performance decrement during the move condition of-32.6%, which greatly exceeded the criteria of performance decrements in the promethazine study comparable to a .15 BAL%. It may be concluded that others with high BAL% scores were also severely performance impaired. It was concluded that there was a substantial negative impact on cognitive and psychomoto performance observed in this study on all three vehicles when operational conditions changed.

Mood states were also derived from a subjective scale. As such these data provide another metric for assessing the subjects perception of the environmental impact on his functional state. Both the activation and affective mood dimensions were generally more negative as the field conditions changed. Further, these mood state responses corresponded to lower physiological response levels (i.e., decreased arousal) and degradation’s in performance.

Sleep data obtained from this study, both on quantity and quality of sleep obtained on nights prior to C2V tests were found to be comparable across vehicles and seats. This was an important measure relative to the goals of this study because significant performance degradation is well documented in response to sleep loss and workload fatigue (Naitoh, 1969). There was considerable variability in the amount of sleep obtained, despite instructions to subjects to avoid late night activities, etc., that would reduce the optimum sleep-waking durations. Subjects in this experiment averaged 6.3 hours per night which is 1.4 hours less than the average sleep duration reported for a comparable group of 20-29 year olds (Tune, 1969).

Physiological data represent an objective index of responses to environmental stimuli. Research by our research group on over 120 subjects showed that there are significant differences in autonomic responsivity (i.e., response variability) related to motion sickness susceptibility. Highly susceptible subjects showed larger response magnitude changes and greater responsitivity to changes in motion sickness inducing stimulus intensity than moderate or low motion sickness susceptibles, (Cowings et. al, 1986). Further, also patterns of autonomic responses to motion stimuli were highly idiosyncratic, the same subjects tended to produce a stable response profile over repeated exposures to stimulations (Cowings, Naifeh and Toscano, 1990; Stout, Toscano and Cowings, 1993).

Analyses of these data show response changes associated with changes in field conditions were comparable across vehicles and seats, with some minor exceptions. The reduction in heart rate when conditions changed from park to move to short halt, for example is consistent with reduced arousal. Because these responses profiles vary widely across individuals, detailed assessment of physiological changes and their correlation to specific performance and symptoms reported would require analyses for each individual subject, which was beyond the scope of this study. This method for assessing individual responses to motion sickness stimuli, however, has been used extensively in past research to determine optimum responses to target for training subjects to reduce response variability and thereby increase both motion sickness tolerance and performance (Cowings, 1990; Cowings.& Toscano, 1997; Kellar, et al, 1993, .Toscano.& Cowings, 1978).

Other factors which may have influenced the results of this study include vibration, prior experience in this vehicle, noise, changes in ambient temperature. Vibration in particular, may have effected visual acuity, in which the greatest impairment occurs at 10-25Hz (Hornick, 1973). Lower frequencies (between 0.12 and .4Hz) have been found to be associated with inducing motion sickness symptoms (McCauley and Kennedy, 1976; Alexander et. al, 1945; and Cowings, 1990). Effects of vibration on manual dexterity as measured by tracking tasks showed greatest number of errors occurred at 5-11Hz (Buckout, 1964). Vibration data obtained from accelerometers mounted at various sites on the vehicle may provide further illumination into this phenomenon. The accelerometers worn on the subject's helmets were used primarily for assessing the average movement across field conditions.

The soldiers selected for participation in this study had relatively little previous exposure to armored tracked vehicles when this experiment began, but by the time tests concluded, had experienced a maximum of 12 course excursions. There is little evidence to conclude that their performance improved with experience, particularly in light of the observation that performance in vehicle 2 (perpendicular) was also degraded, even though these tests occurred late in the experiment design. If anything, there may have been an increase in reports of fatigue and motion sickness symptoms as subjects became more sensitized to the C2V environment.

Although there are undoubtedly numerous other analyses that may be performed on the data obtained from this experiment, we conclude that there is sufficient information to answer the specific questions posed by the army. The preponderance of evidence provided b multiple metrics used in this study lead to the conclusion that (1) there is no significant difference between vehicle configurations and (2) that negative impact on crew performance and health is caused when subjects attending to visual computer screens attempt to operate when the vehicle is moving. The degree of symptoms and performance decay is not substantially reduced by intermittent short-halts.

The problems encountered with the C2V are not platform related but are mission related. Modification of the vehicle is unlikely to result in substantial improvements. The recommendation is that crew selection (of individual with higher tolerance to this environment) or training designed to improve tolerance, be implemented.

References:

Abrams, C., Earl, W.K., Baker, C.H. and Buckner, D.N. (1971). Studies of the Effects of Sea Motion on Human Performance. Human Factors Research, Goleta, CA, Tech. Rep. 798-1.

Alexander, S.J.; Cotzin, M.; Hill, C.J.; Ricciuti, E.A.; and G.R. Wendt. Wesleyan University studies of motion sickness: III. The effects of various accelerations upon sickness rates. J. Psychol. 20: 3-8, 1945.

Billings, C. E.; Demosthenes, T.; White, T.R.; and Ohara, D. B.(1991) Effects of Alcohol on Pilot Performance in Simulated Flight. Aviatio. Space Environ. Med. Vol 62, pp 233-235

Bliss, J.P. (1990). Prediction of Tank-Gunnery Simulator Performance using the APTS Battery. In: Proc. Human Factors Soc. 34th Annu. Meet., Santa Monica, CA, pp. 1328-1332.

Buckhout, R. Effect of whole body vibration on human performance. Human Factors 6: 57-163, 1964.

Cowings, P. S., Billingham, J. and Toscano, W. B. (1977) Learned control of multiple autonomic responses to compensate for the debilitating effects of motion sickness. Therapy in Psychosomatic Medicine, 4, 318-323. And in Luthe, W. and Antonelli, F., eds. Autogenic Methods: Application and Perspectives. Rome: Luigi Pozzi S.P.A., 1977. Also in Barber, T.X. et al., eds. Biofeedback and Self-Control. Chicago: Aldine Publishing Co., 1978.

Cowings, P.S. and Toscano, W.B. (1977). A theory on the evolutionary significance of psychosomatic disease. Therapy in Psychosomatic Medicine, 4, 184-190. And in Luthe, W. and Antonelli, F., eds. Autogenic Methods: Application and Perspective. Rome: Luigi Pozzi S.P.A., 1977.

Cowings, P.S. and Toscano, W.B. (1977). Psychosomatic health: simultaneous control of multiple autonomic responses by humans: a training method. Therapy in Psychosomatic Medicine, 4, 184-190. And in Luthe, W. and Antonelli, F., eds. Autogenic Methods: Application and Perspective. Rome: Luigi Pozzi S.P.A., 1977.

Stewart, J., Clark, B., Cowings, P. S. and Toscano, W. B. (1978). Learned regulation of autonomic responses to control Coriolis motion sickness: its effects on other vestibular functions. Proceedings of the 49th Annual Scientific Meeting of the Aerospace Medical Association, New Orleans, pp. 133-134.

Toscano, W.B. and Cowings, P. S. (1978). Transfer of learned autonomic control for symptom suppression across opposite directions of Coriolis acceleration. Proceedings of the 49th Annual Scientific Meeting of the Aerospace Medical Association, New Orleans, pp. 132-133.

Cowings, P. S. and Toscano, W. B. (1982). The relationship of motion sickness susceptibility to learned autonomic control for symptom suppression. Aviation, Space and Environmental Medicine, 53, (6), 570-575.

Toscano, W.B. and Cowings, P.S. (1982). Reducing motion sickness: Autogenic- Feedback Training compared to an alternative cognitive task. Aviation, Space and Environmental Medicine, 53, (5), 449-453.

Cowings, P.S., Suter, S., Toscano, W.B., Kamiya, J. and Naifeh, K. (1986). General autonomic components of motion sickness. Psychophysiology, 23, (5), 542-551.

Cowings, P. S., Toscano, W. B., Kamiya, J., Miller, N. E. and Sharp, J. C. (1988). Final report. Spacelab-3 flight experiment 3AFT23: Autogenic-Feedback Training as a preventive method for space adaptation syndrome. NASA Technical Memorandum 89412.

Cowings, P.S., Naifeh, K.H. and Toscano, W.B. (1990). The stability of individual patterns of autonomic responses to motion sickness stimulation. Aviation, Space and Environmental Medicine, 61, (5), 399-405.

Cowings, P.S., Toscano, W.B., Kamiya, J., Miller, N.E., Pickering, T. and Shapiro, D. (1990). Autogenic-Feedback Training as a countermeasure for orthostatic intolerance. Proceedings of the First Joint NASA Cardiopulmonary Workshop. Houston, NASA Conference Publication 10068. 145-153.

Kellar, M.A., Folen, R.A., Cowings, P.S., Toscano. W.B., and Hisert, G.L. (1993). Autogenic-Feedback Training improves pilot performance during emergency flying conditions. NASA Technical Memorandum 104005. And in Flight Safety Digest, July 1993.

Cowings, P.S., and Toscano, W.B. (1993). Autogenic-Feedback Training (AFT) as a preventive method for space motion sickness: background and experimental design. NASA Technical Memorandum 108780.

Cowings, P.S., Toscano, W.B., Kamiya, J., Miller, N.E., Pickering, T. and Shapiro, D. (1993). Autogenic-Feedback Training: a potential treatment for postflight orthostatic intolerance in aerospace crews. NASA Technical Memorandum 108785.

Stout, C.S., Toscano, W.B., and Cowings, P.S. (1993). Reliability of psychophysiological responses across multiple motion sickness stimulation tests. Journal of Vestibular Research. 5, (1), 25-33.

Cowings, P.S., Toscano, W.B., Miller, N.E., and Reynoso, S.M. (1993). Autogenic-Feedback Training as a treatment for air-sickness in high performance military aircraft: two case studies. NASA Technical Memorandum 108810.

Cowings, P.S., Toscano, W.B., Miller, N.E., Pickering, T. G., Shapiro, D., Stevenson, S., Maloney, S., and Knapp, J. (1994). Autogenic-Feedback Training: a potential treatment for orthostatic intolerance. Journal of Clinical Pharmacology. 34, (6), 599-608.

Toscano, W.B., and Cowings, P.S. (1994). The effects of Autogenic-Feedback Training on motion sickness severity and heart rate variablility in astronauts. NASA Technical Memorandum 108840.

Cowings, P.S., Stout, C.S., Toscano, W.B., Reynoso, S., DeRoshia, C., and Miller, N.E. (1996). The effects of promethazine on human performance, mood states, and motion sickness tolerance. NASA Technical Memorandum 110420.

Cowings, P.S., Toscano, W.B., DeRoshia, W. (1998). An evaluation of the frequency and severity of motion sickness incidences in personnel within the Command and Control Vehicle (C2V). NASA Technical Memorandum 112221.

DeRoshia, C.W. and Greenleaf, J.E. (1993). Performance and mood-state parameters during 30-day head down bed rest with exercise training. Aviat. Space Environ. Med. 364: 522-527.

Fassbender, C. and K. Goeters. Results of the ESA study on psychological selection of astronaut applicants for Columbus missions. I: Aptitude testing. Acta Astronautica 27: 131-138, 1992.

Fraser. T. The Effects of Confinement as a Factor in Manned Space Flight. NASA Report CR-511, 1966.

Gal, R. (1975). Assessment of seasickness and its consequences by a method of peer evaluation. Aviat Space Environ. Med. 46: 836.

Graybiel, A.; Kennedy, R.S.; Knoblick, E.C.; Guedry, F.E.; Mertz, W.; McLeod, M.E., Colehour, J.K.; Miller, E.F.; and A.R. Fregly. Effects of exposure to a rotating environment (10 RPM) on four aviators for a period of twelve days. Aerospace Med. 36: 733-754, 1965.

Hartley, L.R. (1973). Effects of noise or prior performance on serial reaction. J. Exp. Physiol. 101: 255-261.

Hettinger, L.J., Kennedy, R..S., and McCauley, M.E. (1990). Motion and Human Performance. In: Motion and Space Sickness, G.H. Crampton (ed.), CRC Press, Boca Raton, FL, pp. 411-441.

Hockey, G.R.J. (1986). Changes in operator efficiency as a function of environmental stress, fatigue and circadian rhythms. In: Handbook of Perception and Human Performance, Vol. II, K.E. Boff, L. Kaufman, J.P. Thomas (eds.), Wiley, New York, pp. 44-1 to 44-49.

Hodgson, M.; and Golding, J.F.: Psychometric evaluation of divers performing a series of heliox non-saturation dives. Aviat. Space Environ. Med. 62: 407-413, 1991.

Holding, D.H. (1983). Fatigue. In: Stress and Fatigue in Human Performance, G.R.J. Hockey, ed., John Wiley, New York, pp. 145-167.

Hornick, R.J. Vibration. In: Bioastronautics Data Book, J.F. Parker and V.R. West (eds.), NASA SP-3006, pp. 297-348, 1073.

Hornick, R.J.; Boettcher, C.A.; and A.K. Simons. The effect of low frequency, high amplitude, whole body, longitudinal and transverse vibration upon human performance. Final Report, Contract DA-11-022-509-ORD-3300, Bostrom Research Laboratories, Milwaukee, Wisconsin, July 1961.

Johnson, C. and Wendt, G.R. (1964). Studies of motion sickness. XX. Effects of sickness on performance on code substitution and mirror drawing. J. Psychol. 57: 81, 1964.

Jeanneret, P.R. (1988). Position Requirements for Space Station Personnel and Linkages to Portable Microcomputer Performance Assessment, NASA CR 185606.

Kennedy, R.S.; Baltzley, D.R.; Ostean, M.K.; and Turnage, J.J.: A Differential Approach to Minicomputer Test Battery Development and Implementation. In: Proc. Human Factors Society, 32th Annual Meeting, Santa Monica, CA, pp. 838-842, 1988.

Kennedy, R.S., and Bittner, A.C. (1978). The stability of complex human performance for extended periods: Application for sutdies of environmental stress. In: Proc. 49th Annu. Meeting of the Aerospace Medical Association, New Orleans.

Kennedy, R.S.; Dunlap, W.P.; and J. E. Fowlkes. Prediction of motion sickness susceptibility. In: Motion and Space Sickness, G.H. Crampton (ed.), CRC Press, Boca Raton, FL, pp. 179-215, 1990.

Kennedy, R.S.; Dunlap, W.P.; Turnage, J.J.; and Wilkes, R.L.: Human Intelligence in a repeated-Measures Setting: Commonalties of Intelligence with Performance: In: Current Topics in Human Intelligence, Vol. 3, Individual Differences and Cognition, Detterman, D.K. , ed., Ablex, New Jersey, 1993, pp. 259-281.

Kennedy, R.S. and Graybiel, A. (1965). The Dial Test: A Standardized Procedure for the Experimental Production of Canal Sickness Symptomatolgy in a Rotating Environment. Naval School of Aerospace Medicine, Pensacola, FL, Rep. No. 113, NSAM 930.

Kennedy, R.S.; Jones, M.B.; Dunlap, W.P.; Wilkes, R.L.; and Bittner, A.C.: Automated Portable Test System (APTS): A Performance Assessment Tool. SAE Technical Paper Series, Report No. 81775, Warrendale, PA: Society of Automotive Engineers, 1985.

Kennedy, R.S.; Moroney, W.F.; Bale, R.N.; Gregoire, H.G.; and D.G. Smith.: Motion sickness symptomatology and performance decrements occasioned by hurricane penetrations in C-121, C-130 and P-3 Navy aircraft. Aerospace Med. 43: 1235-1239, 1972.

Kennedy, R.S., Turnage, J.J., Wilkes, R.L. and Dunlap, W.P. Effects of alcohol on nine computerized repeated-measures tests. Ergonomics 36: 1195-1222, 1993.

Kiziltan, M. (1985). Cognitive Performance Degradation on Sonar Operated and Torpedo Data Control Unit Operators after One Night of Sleep Deprivation., unpublished Master's thesis, Naval Postgraduate School, Monterey, CA.

Lachnit, H. and W. Pieper. Speed and accuracy effects of fingers and dexterity in 5-choice reaction tests. Ergonomics 33: 1443-1454, 990.

Lane, N.E.; Kennedy, R.S.; and Jones, M.B.: Overcoming unreliability in operational measures: The use of surrogate measure systems: In: Proc. Human Factors Soc., 30th Annual Meeting, Santa Monica, CA, pp. 1398-1402, 1986.

McCauley, M..E. and Kennedy, R.S. (1976). Recommended Human Exposure Limits for Very-Low-Frequency Vibration, Pacific Missile Test Center, Point Magu, CA, Report No. PMTC 76-36.

McKeever, J. Transportability Test of the Command and Control Vehicle (C2V) (Ride Quality and Road Shock and Vibration Tests). U.S. Army Aberdeen Test Center, Aberdeen Proving Ground, MD, Report No. 98-AIT-083, 1998.

Mullins, L.L.; Fatkin, L.T.; Modrow, H.E.; and Rice, D.J.: The relationship between cognitive performance and stress perceptions in military operations. In: Proc. Human Factors & Ergonomics Society, 39th Annual Meeting, San Diego, CA, pp. 868-872, 1995.

Naitoh, P. (1969). Sleep Loss and its Effects on Performance. Navy Medical Neuropsychiatric Research Unit, San Diego, Report No. 68-3.

Parker, D.M. (1969). Effects of seasickness on error scores in mirror tracing. J. Gen Psychol. 81: 147.

Palinkas, L.A. The Human Element in Space: Lessons from Antarctica. Naval Health Research Center, San Diego, CA, Report No. 88-8, 20p., 1988.

Poulton, E.C.; and B. Chir. Environment and Human Efficiency, C. Thomas, Springfield, 1970.

Poulton, E.C.; and D.M.K. Kerslake. Initial stimulating effect of warmth upon the perceptual efficiency. Aerospace Med. 36: 29-21, 1965.

Rosa, R.R. and M.J. Colligan. (1988). Long workdays versus restdays: Assessing fatigue and alertness with a portable performance battery. Human Factors 30: 305-317.

Schmitz, M.A.; Simons, A.K.; and C.A. Boettcher. The effect of low frequency, high amplitude, whole body vertical vibration on human performance. Report 130, Contract DA-49-007- MD-797, Bostrom Research Laboratories, Milwaukee, Wisconsin, January 1960.

Smirichevskiy, L.D. Investigation of operator activity during the accomplishment of typical functions under conditions which simulate long-term space flight. In: Psychological Problems of Space Flight. (Russian). B.N. Petrov, B.F. Lomov and N.D. Samsonov (eds.), Nauka, Moscow, pp. 54-59, 1979.

Stanny, R.R. Modeling for Human Performance Assessment. NAMRL Annual Report Contract No. MIPR 90MM0523, Naval Aerospace Medical Research Laboratory, Pensacola, FL, November 1990.

Tirre, W.C. and K.K. Raouf. Gender differences in perceptual-motor performance. Aviat. Space Environ. Med. 65(Suppl.): A49-A53, 1994.

Tukey, J.W. Exploratory Data Analysis. Addison-Wesley, Reading, MA, 1977.Turnage, J.; and Kennedy, R.S.: The development and use of a computerized human performance test battery for repeated-measures applications. Human Performance 5: 265-301, 1992.

Webb, W.B. (1968). Sleep: An Experimental Approach., MacMillen, New York.

Weybrew, B.B.; and E.M. Noddin. Psychiatric aspects of adaptation to long submarine missions. Aviat. Space Environ. Med. 50: 575-580, 1979.

Wiker, S.F. and Pepper, R.L. (1978). Changes in Crew Performance, Physiology and Effective State Due to Motion Aboard a Small Monohull Vessel. Coast Guard Tech. Rep. No. CG-D-75-78.